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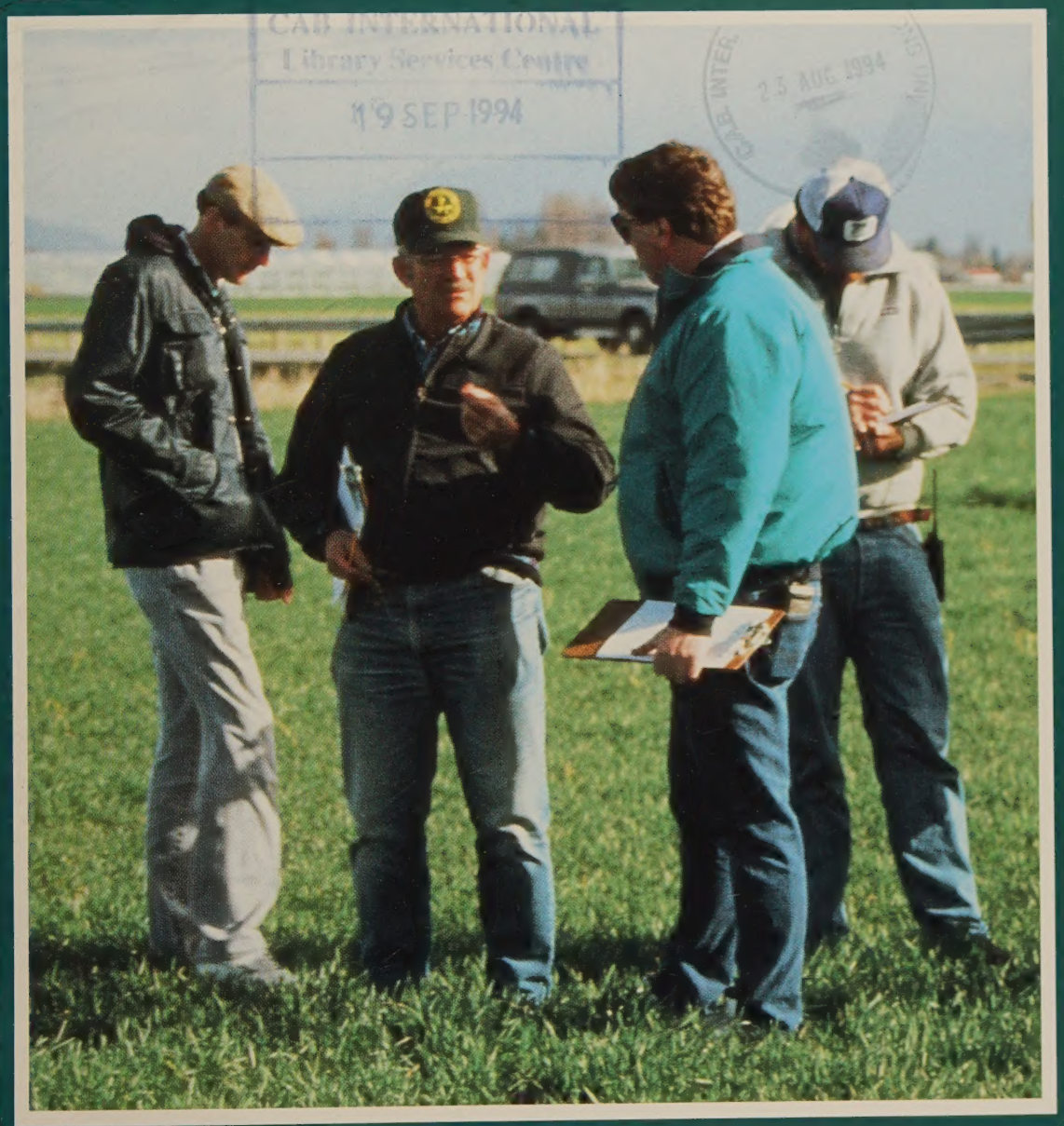

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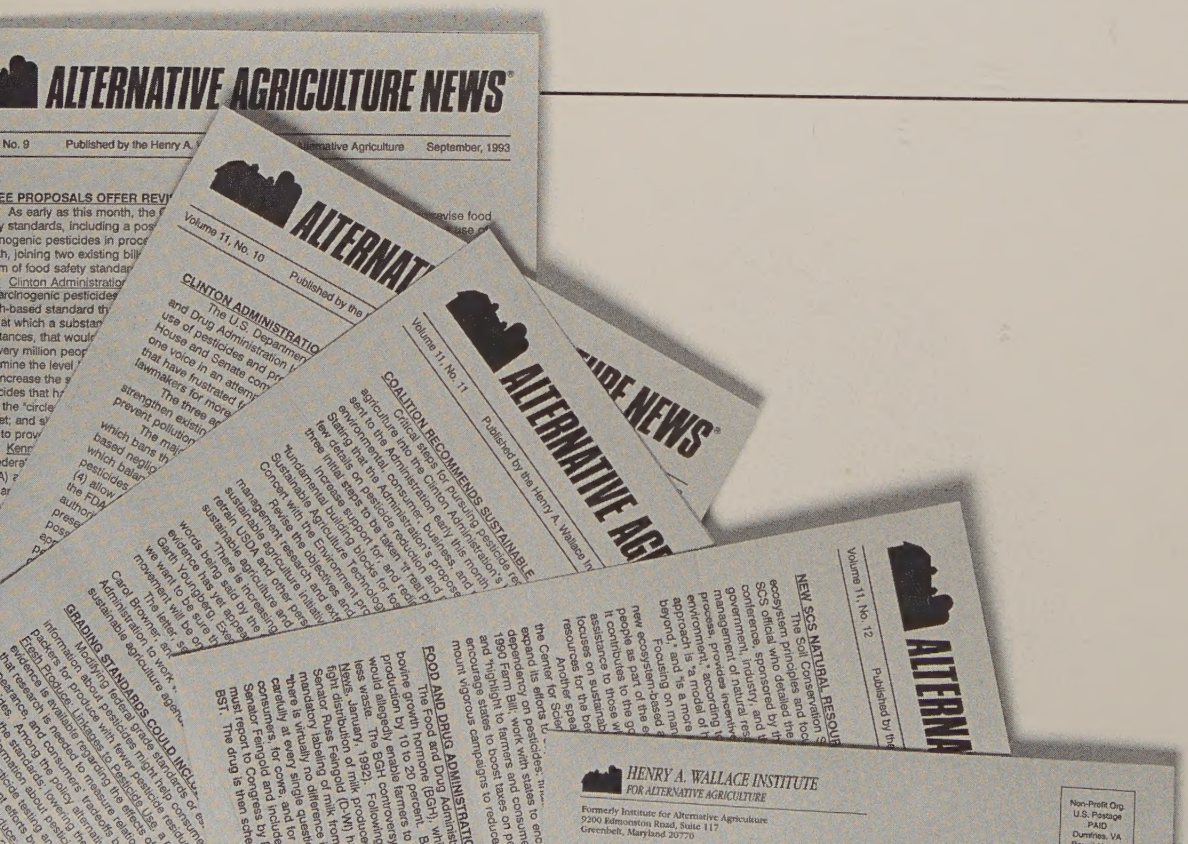

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In northwestern Washington's Skagit Valley, focus group members and cooperating growers evaluate on-farm cover crop research as part of Washington State University's *Cropping Strategies and Water Quality Project*. Photo supplied by the Center for Sustaining Agriculture and Natural Resources, Washington State University, Pullman.

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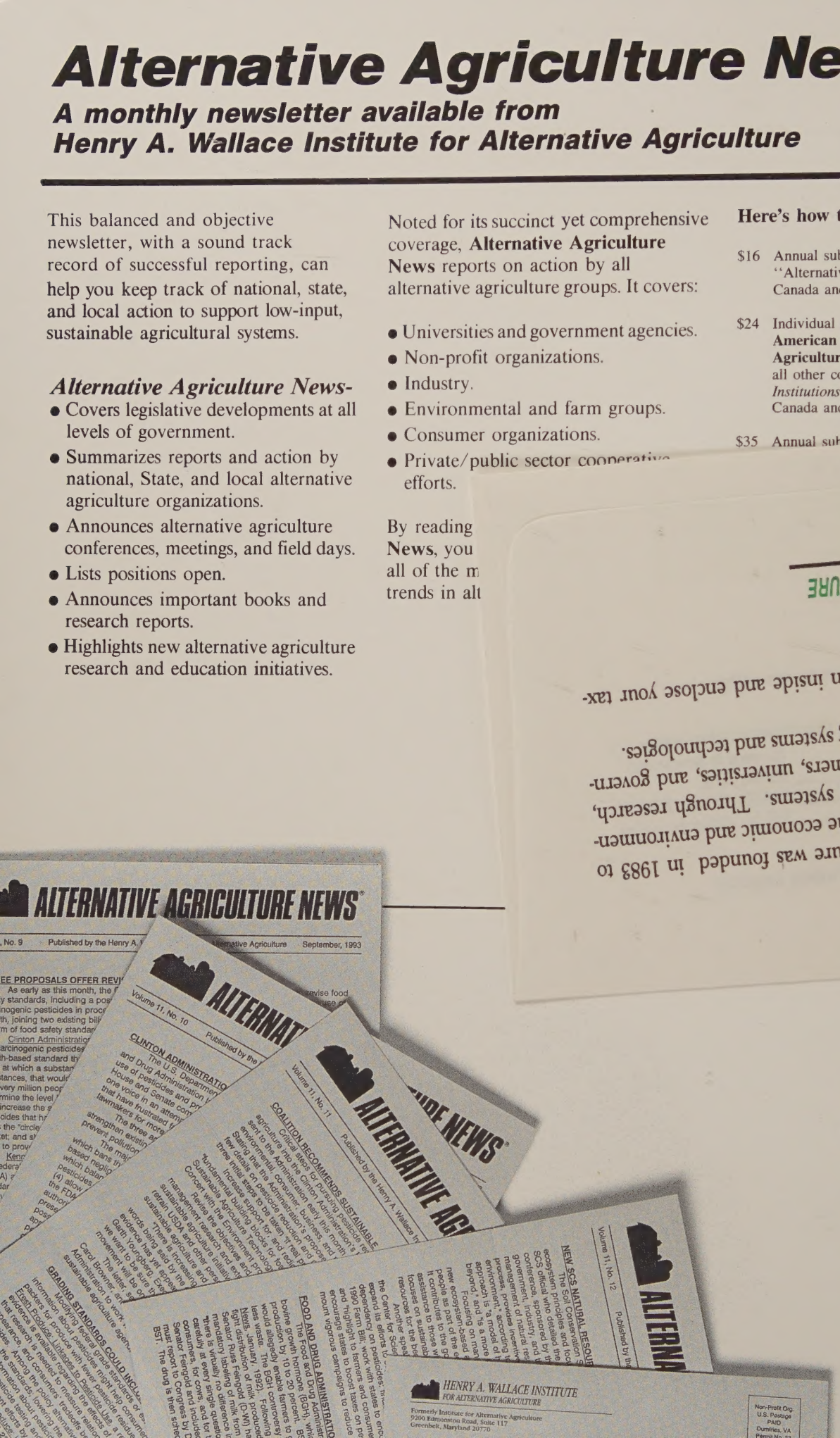

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The Conference on Science and Sustainability: Its background and origins

Traditional ways of conducting agricultural research and education are rapidly changing as land-grant institutions move from a production orientation to one that includes more environmental, social, and ethical concerns. The shift from a largely rural to a largely urban population has affected public perceptions of agricultural research because most people now are separated both emotionally and physically from their sources of food.

The academic community recently has been shifting toward basic rather than applied and problem-solving research. This is due in part to the reward system's greater emphasis on publications, which discourages long-term and applied research and promotes disciplinary and reductionist rather than systems approaches.

With continuing reductions in support for agricultural research and extension, and with the land-grant mandate broadened to include environmental and social issues, farmers often feel that the land-grant institutions have let them down. As pointed out by John Ikerd ("The question of good science," *AJAA* 8:91-93, 1993), farmers tend to be more interested in applied research results that provide knowledge about specific subjects or that help solve problems. In contrast, the scientific community usually places a higher value on research that develops concepts and theories or that improves research techniques. Ikerd further notes that farmers need information that reduces their risk of making wrong *decisions*, whereas scientists may be more concerned about the risks of misinterpreting their research results and thus drawing wrong *conclusions*.

In contrast to more traditional styles of agricultural research, farmers were given a much greater role in the Low-Input Sustainable Agriculture program, which later became the Sustainable Agriculture Research and Education (SARE) program. These programs, which promoted a systems approach to research, were initiated by the U.S. Congress in response to environmental and economic concerns. In the early 1990s, the SARE coordinator for the Western region, Dr. David Schlegel, conceived the idea of a conference on "the science of sustainable agriculture" in response to some researchers' doubts about the scientific validity of research on sustainable agriculture.

After several attempts to get an institution to take the lead, CSANR at Washington State University agreed to cosponsor the conference with the Western SARE program. A planning committee was formed to develop the agenda. However, it soon became apparent that the physical and social scientists differed completely regarding the objectives, approaches, and outcomes of a conference on the science and sustainability of agriculture. The difficulties in agreeing on an agenda showed that there was more than sufficient justification for holding a conference. Therefore, we decided to focus the conference not on defining "good science" (Ikerd, 1993), but instead on presenting examples of existing research and education projects spanning the continuum from traditional, reductionist approaches to interdisciplinary, qualitative and whole system studies. We wanted to show how partnerships among university specialists can enhance the economic, social, and ecological viability of agricultural systems.

The conference had several components: keynote speakers to introduce the subject; presentations of integrated/whole farm case studies; workshops on systems research and education; and breakout sessions on institutional barriers facing interdisciplinary research and education. The projects represented a range of activities: experiment station studies of crop and crop-livestock systems, focus groups, and on-farm research. Karl Stauber of the Northwest Area Foundation gave a keynote address that challenged us to rethink our mission as agricultural researchers and to consider several models for change. Deputy Secretary of Agriculture Richard Rominger presented the evening keynote address on the role of USDA in shaping agricultural research and education.

The conference emphasized a process rather than specific products; we hoped this would distinguish it from other sustainable agriculture conferences. We did not want the type of presentation that is customary at professional society meetings. Rather, we were interested in why and how each study was designed, the participants in the process, the anticipated products, and how the results were disseminated. Several researchers talked about their frustrations in conducting systems research because of the greater time commitment required, the longer time before publishable results are obtained, the lack of acceptance of nontraditional statistics, the difficulties in deciding authorship of papers, and the risk of not getting promotions and tenure. However, most scientists were very satisfied about carrying out systems research and education because of the holistic approach and the synergies from working with people from many walks of life.

More than 200 participants from 35 states and 5 countries attended the conference. Unlike some sustainable agriculture meetings where the "choir" dominates, many people from the traditional agricultural community attended, including several land-grant administrators. The meeting gave us the feeling that many sustainability issues that were discussed are slowly becoming institutionalized, a positive sign. Most of the keynote talks and case studies are included in this issue. In addition, written documentation of the four workshops and four breakout sessions will be published by CSANR.

As Conference Chairman, and on behalf of the planning committee, I wish to thank the Henry A. Wallace Institute for Alternative Agriculture for agreeing to publish these presentations, and especially William Lockeretz for editing them. Thanks go also to conference coordinators Colette DePhelps and Norma Fuentes Scott, the contributing authors, and the planning committee.

David Bezdicek
Director, Center for Sustaining Agriculture and Natural Resources, Washington State University, Pullman, WA 99164.

Innovative approaches for integrated research and educational programs

David F. Bezdicek and Colette DePhelps

Abstract. *Over the past half century, American agricultural productivity has increased while the number of full time farmers and rural populations have decreased. Although most people believe we have a safe, nutritious, and affordable food supply, the high level of productivity has had negative impacts on the environment and rural communities and has increased farmers' dependence on purchased inputs. As Americans become more concerned about food safety and the environment, a new paradigm for American agriculture is emerging. This new alternative agriculture takes an ecological approach to food production. The challenge facing the land-grant university system is how to answer questions about sustainable agricultural systems, maintain productivity and respond to the needs and concerns of their broadened clientele. Whole farm case studies, focus groups, farm improvement clubs, on-farm research, field-size research trials, and whole farm comparisons are new qualitative and quantitative methods for interdisciplinary research and education. These methods integrate biological and social strategies and bring community members into the research and education process. When these groups work together, questions critical to maintaining the long-term sustainability and productivity of agricultural systems can be answered.*

Key words: sustainable agriculture, participatory approaches, integrated systems, interdisciplinary research

Introduction

A century ago, when over 40% of the U.S. population lived on farms, most farmers had little or no university education or technical training. New knowledge, science and technology, fostered by the Morrill, Hatch, and Smith-Lever Acts, solved many problems associated with rural poverty, and increased farm production to unprecedented levels not previously attained elsewhere in the world. The linear model of teaching → research → extension → farmers became the standard operational mode for the land-grant institutions, but it is being challenged today as more farmers are university educated and fewer scientists have farm experience.

Today, less than 2% of the U.S. population lives on farms, a statistic often used to show the productivity and efficiency of American agriculture and to boast about our current structure. However, our high level of productivity has hidden costs, including the loss of rural communities, degradation of the resource base, increased reliance on purchased inputs, and increased regulation. With more than half the U.S. population now living in suburbs, the average consumer has little knowledge or appreciation of our food system and little awareness of the connection between food and farming. As Stauber (1993) has pointed out, consumers are more concerned about food quality and safety than production efficiency. Also, they are more likely to see the "garden" as the best image for human survival rather than the "factory" suggested by industrialized agriculture.

As a result, expectations for the land-grant system, beyond the traditional mandates of production agriculture, are greater than ever. They include many social concerns, such as environmental quality, resource conservation, food safety, and the safety of farm workers. Incorporating society's new expectations into the traditional, linear model of university research and extension has met with many obstacles. Our current emphasis on teaching, research, and extension programs driven by commodity considerations and disciplinary perspectives is being challenged to meet future goals and expectations.

Few people would disagree that the land-grant university system's past research and extension activities played a decisive role in establishing today's agricultural systems. Many agree that our food system is among the safest in the world and that it is economical for the average American consumer. What is unclear is what role the land-grant university system will play in shaping future agricultural systems. The prevailing perception is that the university research and extension agenda must be broadened to attract new constituencies and meet the needs of its new clientele (Miller, 1990; Thornley, 1990). However, some people disagree. Merrigan (1993), for example, believes that Cooperative Extension must narrow its agenda and focus its energies to do one job well.

David F. Bezdicek is Director of the Center for Sustaining Agriculture and Natural Resources and Professor of Soil Science, and Colette DePhelps is Outreach Coordinator, Center for Sustaining Agriculture and Natural Resources, Washington State University, Pullman, WA 99164.

A New Agricultural Paradigm

Central to the discussion of the land-grant universities' research and educational mandate are the paradigms and models representing "conventional" and "alternative" agricultural systems, respectively. Beus and Dunlap (1990) identified six major dimensions characterizing these divergent paradigms, as shown in Table 1. These represent extreme points of view; our current system includes elements of both, but the trend over the years has been a shift toward the conventional end. Conventional and alternative practices in the real world are not static; rather, they change constantly.

Table 1. Contrasting elements of competing agricultural paradigms.

Conventional systems	Alternative systems
centralization	decentralization
dependence	independence
competition	community
dominance over nature	harmony with nature
specialization	diversity
exploitation	constraint

Adapted from Beus and Dunlap, 1990

The debates over the structure of agriculture can also be interpreted in light of prevailing alternative world views. Two opposite but pervasive world views can be described as Anthropocentric vs. Ecological. Conventional, industrial models of agriculture based on single discipline research and extension are generally associated with an anthropocentric world view. An ecological approach emphasizes alternative, nonindustrial types of agricultural systems based on an understanding of the interactions between humans and the ecosystem that is derived from interdisciplinary and participatory research and education.

Alternative and conventional agricultural systems might also be interpreted in view of Stauber's (1994) presentation of three visions of the common good: 1) the romantic vision in which individuals fight societal complacency by doing what is right; 2) the liberal vision, which emphasizes individual consumption and expects competition led by corporate and government elites to solve society's problems; and 3) the ecocentric vision, which emphasizes the human element and promotes the survival of all species. Stauber (1994) suggests that more reliance on the conventional-industrial agricultural models will force experiment stations out of business in 10 to 20 years, and that reliance on conventional commodity-focused models will require only 10 to 12 experiment stations. This would close many regional experiment stations that normally help farmers address local production and environmental problems. Instead of focusing on one vision, we should consider a compromise that combines the liberal and ecocentric visions of the common good, a compromise the suburban majority and political structure will support because they support human, environmental, and ecological values.

Creating an agricultural paradigm based on a combination of the liberal and ecocentric visions of the common good requires new models and partnerships for agricultural systems research and education. Rather than being narrowly focused, these new agricultural models must integrate the research methods currently used in the biological and social sciences, creating new system-level strategies for solving problems associated with agriculture and natural resource use. These models also must involve partnerships in which biological and social scientists are team players rather than independent designers of experiments. Combining the quantitative methods used by physical scientists and biologists with the qualitative and quantitative methods of social scientists will provide synergies not achievable in disciplinary isolation and will insure better acceptance by the public.

New Qualitative and Quantitative Methods

Establishing interdisciplinary university research and education teams is only the first step in addressing the critical questions facing American agriculture (DePhelps and Butler, 1992; DePhelps, 1993). Partnerships need to be formed between university specialists and community interest groups concerned with the economic, social, and ecological viability of agriculture (Fig. 1). Together, these traditionally separate interest groups can develop a common vision of future agricultural systems.

New models are emerging for integrating quantitative and qualitative methods and forming partnerships between diverse communities. Many of these models recognize that future experiment stations for research and education will include farmers' fields. On-farm experimentation takes place in an environment that potentially represents farmers' typical management practices. Such research holds promise for producing information directly applicable to field situations. The challenge is to learn how to analyze and interpret data generated by on-farm experimentation so that it produces results acceptable both to other farmers and to the scientific community.

These models for generating new agricultural knowledge involve not only the physical and biological sciences but also the socioeconomic concerns of humans who affect or are affected by agricultural practices. Socioeconomic research needs to investigate how to motivate behavioral change and why different interest groups, such as conventional farmers, often resist change (Batie and Swinton, 1994). We also must study the impacts of such change (Biggs, 1989). In addition, Lockeretz (1994) maintains that the expertise of non-land grant institutions could increase the breadth of scientific understanding of human and ecological systems. Increasing the knowledge base will enable agricultural researchers to embrace the complexities of

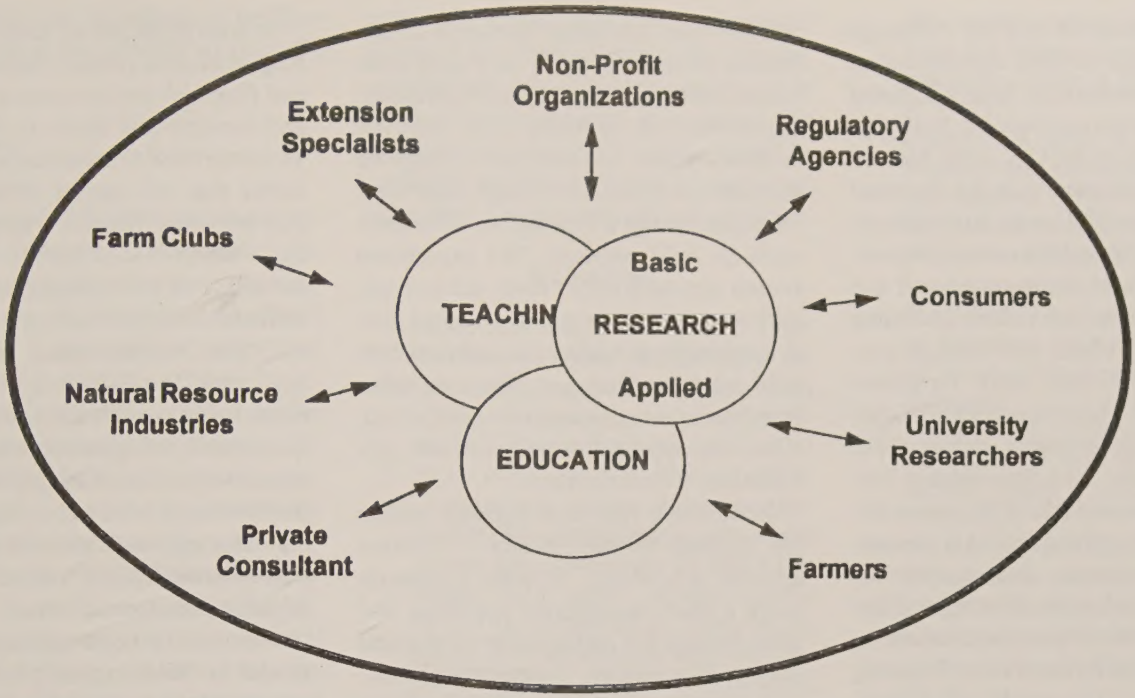

Figure 1. New Land Grant University Research and Education Model.

the entire agricultural system. Traditional agricultural scientists may resist this transition from the land-grant university researcher as the exclusive source of ideas and data to an arrangement in which ideas and data also are generated by non-land grant university researchers and by farmers.

The following are some examples of innovative methods being used in integrated, whole farm studies. Each provides a model for integrating socioeconomic research with more traditional biological approaches to agricultural research. These methods also use nontraditional information sources, such as farmers and members of community interest groups, to increase the understanding of the system.

Whole farm case studies. Case studies are systematic examinations of the physical, biological, social, and economic features of entire farming systems over time. They are conducted by multidisciplinary teams who examine economic factors, production practices, business management, goals, and relations between farmers and employees. Case studies are common in business, economics, and medicine, and rely on qualitative information not achievable through controlled experiments. Agricultural case studies have been used, among other places, in interdisciplinary teaching programs at the University of Minnesota (Stanford et al., 1992), in the National Research Council's (1989) report *Alternative Agriculture*, and in a characterization of small fruit and vegetable farms in western Washington and Oregon (Murray and Butler, 1994).

Focus groups. Focus groups and interviews are a way of seeing how different people view a particular problem. Murray and Butler (1994) reported on a Skagit County, Washington, focus group of 16 people formed to study how cover crops can reduce seasonal nitrate leaching, reduce erosion, offer cover for wildlife, and build soil organic matter. Results from a combination of on-farm cover crop tests and experiment station trials have reached an audience of two thousand people, including farmers, wildlife and environmental interest groups, scientists, regulatory agencies, and schoolchildren. The focus group also has achieved grower acceptance and has lead to a dialogue among diverse interest groups. Lev et. al. (1993) present case studies of how focus sessions allowed farmers and scientists to discuss economical disposal of food production wastes, alterative weed control methods, and food safety concerns.

Farm improvement clubs. Started by the Alternative Energy Resources Organization (AERO) in Montana, farm improvement clubs offer the opportunity for small groups of producers to work together to share their experiences in solving common problems. The agenda, which is set by the club members themselves, covers community education, farm and community development, and scientifically based research. Farm experiments study alternative crops, legumes in rotation, summer fallow replacement, and livestock grazing. Small grants of $300 to $800 are available from several donors to offset producers' cost for seed, travel, and soil tests. University scientists and other agencies often cooperate in carrying out the studies. Community support clubs, a concept introduced by AERO and the Palouse-Clearwater Environmental Institute, complement farm improvement clubs by promoting the concept of sustainable agriculture within local communities.

On-farm research (OFR). Although scientist-initiated on-farm demonstration and research is an old idea, farmer-initiated on-farm research is more recent. Early on-farm researchers in the U.S. were Richard and Sharon Thompson with the Practical Farmers of Iowa (PFI), who in collaboration with Iowa State University Cooperative Extension have shown that small and medium sized farms can be both profitable and ecologically viable with reduced purchases of pesticides and fertilizers (Thompson and Thompson, 1990). Other on-farm research programs include those conducted by the Land Stewardship Project in Minnesota and REAP (Resource Efficient Agricultural Production) in Canada. On-farm experiments often use narrow strips running the length of the field. They may be replicated within a field, or among different fields on the same farm, or among different farms. The results are statistically comparable to experiment station trials, but have the added advantage that they were obtained using equipment typically used by farmers. As a result, their results are accepted better by other farmers who farm under similar conditions.

A well-designed on-farm experiment will not necessarily replace experiment station trials, but can foster a working relationship between farmers and scientists, capturing the knowledge and skills of both and providing reliable outreach to other farmers (Rosmann, 1994). PFI acknowledges that sustainable agriculture is more than a set of farming practices, and includes humans and their values. The PFI program has led to other on-farm efforts such as those conducted by the Progressive Farmers Inland Northwest in Washington State and within STEEP (Solutions to Economic and Environmental Problems), a federally funded program in Washington, Oregon, and Idaho. The composition of the on-farm research team need not be limited to farmers and researchers. For example, in Skagit County, Washington, community interest groups were involved in on-farm research to abate nitrate pollution of groundwater, resulting in increased educational and funding opportunities (Murray and Butler, 1994). Results are available from on-farm trials in the Pacific Northwest (Wuest et al., 1994) and from PFI (Schauer, 1992), among others.

Field-size systems research trials. Studies of entire systems on a field scale complement the more typical experiment station research, in which a few variables such as fertilizer rate and type of tillage are studied in a replicated design, and other variables having a bearing on the experiment are held constant. The experiment station approach offers many advantages, such as access to the site and control over it, availability of equipment, and closeness to laboratories. However, plot-scale rather than field-scale equipment is usually used. Also, this approach usually studies only variations within a system.

In contrast, field-size systems studies can compare the performance of different systems as a whole. Systems studies require a multidisciplinary approach and often include the participation of physical and social scientists, Cooperative Extension, producers, industry, and Federal and state governments. For these studies to be successful, it is essential for the primary participants to be involved from the time the project is conceived.

Typical field-size systems studies often compare conventional rotations to those including legumes or livestock, and often include a treatment involving organic management or reduced use of purchased inputs. They often use full-size equipment on either experiment stations or farmers' fields. An early systems study was done at the Rodale Research Center in Pennsylvania (Liebhardt et al., 1989). More recent studies highlighted at the Science and Sustainability Conference include those on cereal production in the Pacific Northwest (Young et al., 1994), tomato production in California (Temple et al., 1994), and livestock systems in Virginia (Luna et al., 1994).

Paired farm and whole farm comparisons. Often it is not possible to establish research plots to learn the long-term economic, social, and ecological effects of different farming practices. Using practicing farms as "alternative experiment stations" can yield valuable long-term information on different production systems, since producers' practices and farm-scale operations have direct application to real world problems. The greatest difficulties associated with this method are to select the farms appropriately and to do the proper statistical analysis.

In a series of paired farm comparisons, Reganold et al. (1993) studied soil quality and financial performance of biodynamic and conventional farms in New Zealand. To insure reliable statistical analysis and to insure that soil quality differences were due only to differences in management, they examined soils from the farms before the study. In farm comparisons where it is difficult to find paired farms with identical soil type, nonparametric statistics have been used. In a California study, Workneh et. al. (1993) evaluated differences in soil quality and pathogen/pest/nutrient interactions in organic and inorganic tomato production using principal component analysis. This approach allowed them to compare systems in place without having to establish replicated field trials.

Another systems and team building model is Washington's Integrated Resource Management Program/Strategic Ranch Management (IRM/SRM). Its goal is to increase profitability and sustainability through whole-ranch analyses, planning, and alternative enterprises. The program's primary objective of strengthening producers' decision making abilities is accomplished through team-building, effective communication, and collaboration.

Educational Programs

New models for educational programs in the 21st century will need to look at how multistate institutions, industry, agencies and others can help each other develop practical curricula on agroecosystems. The traditional boundaries between teaching, research, and extension are likely to be much less clearly defined, with the three cooperating more than in the past. In many land-grant institutions, integration occurs already, although the mandates and funding sources of the three activities differ. New educational programs must emphasize new paradigms of experiential and lifelong learning, problem solving and case studies as alternatives to our present educational system (Francis and King, 1994). Regional efforts involving new partnerships among land-grant colleges, state and community colleges, industry, regulatory agencies, and service organizations will be new components of future agricultural education. Modern advances in telecommunications will allow students to receive

up-to-date courses regardless of location and will reduce the number of teachers needed.

Summary

Systems approaches to agricultural research and education emphasizing the qualitative and quantitative methods mentioned here are not panaceas, and cannot address all the complexities of agricultural systems. Rather, they are options for increasing communication and collaboration among researchers and other groups traditionally isolated from each other as they seek to identify and promote scientifically based sustainable agricultural systems.

Obviously, we will continue to need basic research to underpin applied research. Systems research requires basic research as a fundamental partner. Much of the mission-oriented research at our land-grant universities and USDA's Agricultural Research Service requires basic science as part of a team effort. For example, understanding the basic biology of predator-prey relationships, human decision-making processes, interactions between plants and root pathogens, and plant-insect communication is fundamental for the future of biological control to reduce our dependence on pesticides. Involving non-land grant university institutions in agricultural research will contribute to the basic understanding of biological and human systems and offer fresh perspectives on complex problems.

New funding programs, such as the Agriculture Systems component of the National Research Initiative, show that we have recognized the importance of complementary basic and applied research programs that incorporate knowledge of both biological and human systems. New educational programs integrating the biological and social sciences will produce researchers and educators trained to address agricultural questions on a systems level. This is critical as we respond to the complex environmental and social concerns of consumers while considering the production and economic priorities of growers.

"Good science" should continue to be a priority in agricultural research. However, with today's budget constraints, good science for science's sake is not good enough. Other things being equal, good science that is part of a systems approach by a mission-oriented team should receive priority over good science conducted in isolation. As resources become more scarce, it will be necessary to use more regional approaches to problem solving that reduce duplication.

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LETTER

Modern agriculture: Still agrarian-based

In their excellent article on agricultural policy debates (*AJAA* 8(3):98-106), Beus and Dunlap make a couple of passing references to "modern industrialized agriculture." They join a host of persons who write in a similar vein.

They would be more empirically accurate if they were to refer to "partially industrialized agriculture." Even better would be to say that today's farming superimposes industrial materials and processes on a still-agrarian resource base. The industrial overlay has never really fused with the soil-water-organic nutrient base. Nor will it. The two are essentially incompatible, and the base remains agrarian.

A quarter-century ago, at an international conference held in Switzerland, renowned food technologists scratched each other's egos in predicting a bounty of synthetic foodstuffs to be derived from converting the hydrocarbons of fossil fuels into carbohydrates for human nutrition. The two or three of us economists were scorned when we warned about relying on a depletable resource for the world's food supply. The technologists were describing a truly industrial food system. Ours is not that.

I do not minimize the significance of our introducing industrial materials, primarily energy sources, into our farm and food system. I explored the subject in my article "The Three Economies of Agriculture," published in *Journal of Farm Economics* (August, 1962). The three economies were: 1) "producing primary products from that unique resource, the soil"; 2) production of livestock; and 3) "the long and complicated process of marketing." The marketing system is, of course, the most industrial of the three economies. Production of crops from soil has been the least so, but—the point of the article—in our century industrial materials and processes have been introduced, giving it a more industrial composition than it had previously.

In 1962, the livestock sector was at an intermediate level of industrialization. Since then it has become much more so, as huge cattle feedlots and hog operations that justify the term "factory" have given it a more industrial character.

In recent years I have written about the imminence of a shift backward from the industrial model, a shift forced by environmental concerns but much more by gradual depletion of the world's fossil fuel reserves. The turnaround will be dramatic in the livestock sector, where factory-style operations depend critically on inexpensive energy. Furthermore, there is no basic economy in feeding human food (corn, for example) to animals just to be able to eat ham instead of pasta.

Of more interest to readers of this journal is my observation that sustainable and other forms of alternative agriculture anticipate the swing I foresee back toward a more agrarian agriculture. What is so intrinsically distinctive about the agrarian base? First is its unique resource of the soil, which leads to an injunction to take protective measures lest civilization collapse. The crucial role of water as a conveyor of nutrients comes next to mind. Less often recognized is another distinctive mark, the nonsimultaneity of processes in the growing of plants from which we get our crop harvests. The discipline of the seasons is the most familiar example, and it is imperious. Until all three features can be manipulated or made to disappear by pushing a button on a computer, our agriculture will continue to be only partially industrialized and, in a true sense, incompatibly so.

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Letters To The Editor Invited

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The futures of agriculture

Karl N. Stauber

Abstract. *One widely held view of the future of American agriculture is that it will continue the current trend toward fewer but larger farms, greater centralization and vertical integration, and declining rural populations. If so, the research, teaching and extension institutions created to serve agriculture will not survive unless they can adapt to changing political and demographic conditions, especially the domination of the suburbs. This will require these institutions to set new goals for themselves. Their historic pursuit of increased technical efficiency already has been so successful that it has sharply reduced the farm population, which has been their main base of public support. Suburban America, in contrast, will demand an agriculture that is more in harmony with nature. Alternative notions of the Common Good can provide the philosophical basis for this shift. Historically, the economic system, including agriculture, has regarded nature as something to be used to advance human well-being. In this view (which could be called "Liberal" in the 19th century sense of the term), the reason to protect nature is to insure that it can continue to serve human needs. In contrast, the "Ecocentric" view of the Common Good emphasizes that humans are part of an ecological community, and that we must optimize the balance between human needs and the health of the ecosystem.*

Key words: agricultural policy, environmental protection, Common Good theory, institutional change, institutional survival

What is the future, or more accurately, what are the futures of American agriculture? Are we, as suggested by various studies, headed toward an industrialized future where today's 2.1 million farms are replaced by several hundred thousand highly intensive operations concentrated in the most productive artificial ecosystems, with the rest of rural America converted to other uses or to the "Buffalo Commons"—a future where agriculture effectively is replaced by "agrimation?" Or, as some have called for, are we headed back to the time of the small- to middle-size "Family Farm," where many rural people live in substandard houses at near poverty-level incomes—a return to near-subsistence farming?

Are these the only two options—the industrial agriculture of our current model or the romantic agriculture of the past? Could we not intentionally create an agriculture that attempts to bring together economic opportunity and environmental quality? How do we create this third option, this ecocentric agriculture?

Does the public want a third option for agriculture? Does the public care about the future of agriculture? Is it willing to invest in that future? What is the role of publicly supported science under this third option? Is modern agricultural science, with its heavy emphasis on single values and replication, able to serve the more complex objectives of sustainability? How should the delivery and financing of science be restructured to support increased sustainability, rather than just increased production?

Posing these questions presumes we first have answered an even more fundamental question: Does agriculture have a future? The answer is yes, because the average citizen will continue to need about 2,000 to 2,500 calories per day of nutritionally balanced food. Wool, cotton, and other grown fibers will continue to clothe us. Oilseed and fiber crops will be used in increasing amounts as alternatives to the nonrenewable or environmentally-sensitive resources currently used as feedstocks for industrial production.

However, surplus production of commodity crops, which has been a problem for most of this century, is likely to remain so under the current system, threatening the stability of American agriculture. Per capita domestic demand for farm output, which has been nearly stagnant for 20 years at about 1,400 lb/year, is expected to grow by less than 1% per year through the year 2000 (O'Brien et al., 1990). The demand for food will remain inelastic; combined with increasing production, this will mean lower commodity prices unless the surplus is offset by increased exports (Buttel, 1990).

But farmers cannot count on world markets. The U.S. share of world agricultural exports has decreased from 40% in 1960 to 21% today (O'Brien et al., 1990). Long-term growth of the world agricultural market is not expected to exceed 4.5% per year (O'Brien et al., 1990). The future of U.S. farmers also will be affected by whether the so-called developing nations, which is where most of the growth is expected to occur, will be able to pay for more imports and whether the U.S. will have cheap dollars and cheap commodities.

Looking ahead, the mixed policy signals are striking. In recent decades, farmers' decisions have been focused more on government policy and less on markets. Consumers started to show concern about food safety. Off-farm employment became the major source of income for most American farm families. Since 1980, farms have become more capital intensive, mechanized, specialized and intensified, and rural communities have become increasingly dependent on exports, income from outside

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agriculture, and federal payments (Flora, 1990).

Many people think new technology is the answer to farmers' economic problems. Technology has made U.S. agriculture one of the most productive in the world. Some studies show that the new technologies needed if the U.S. is to maintain a competitive international position will cause major changes for farmers at least until the year 2000 (Office of Technology Assessment, 1986). The next wave—biotechnology and infotechnology—may cause even greater changes than those produced by the combined mechanical and chemical innovations of the twentieth century. Some studies suggest that many new technologies will be environmentally positive (Office of Technology Assessment, 1986). Such technologies may benefit rural market centers and communities where the number of small and part-time farmers is increasing. Other rural communities in more isolated areas that are dependent on agriculture probably will be hurt.

The proponents of increasingly industrialized agriculture believe the structure of agriculture must change to accommodate new technology; farming will become more centralized and more vertically integrated, large farms will become dominant, and moderate-size farms will vanish, hurting rural areas. According to a study by the Office of Technology Assessment of the U.S. Congress (1986), we can expect to have a total of 1.25 million farms by 2000, with 50 thousand farms (4%) accounting for 75% of all agricultural production.

There are alternative voices, however. In the U.S., approximately 1% of the population produces most of the country's food, and enough for export. What is to be gained by further reducing the number of farmers? Some argue that America doesn't need more food output, it needs less environmental destruction (Strange, 1988, pp. 221-223). The real question is not "Does agriculture have a future?" but "Who will produce food and how will they produce it?" The answers will determine not only the future of many farmers, but the fate of the land-grant universities and other institutions created to support farmers.

Origins of Our Agricultural Institutions

It is easy to fall into the trap of assuming that things will continue as they have in the past. This is a trap in two ways: it assumes that the past is like the present and that the future will be a linear extension of the present.

Galbraith (1987) suggests that to understand an institution one must first understand the conditions that led to its creation. Institutions are a product of a particular time and place, a set of values. Given that societal change is constant but not consistent, institutions must change. When institutional change is out of synchrony with societal change, conflict arises.

What are the conditions that led to the creation of the modern farm and its related institutions such as the land-grant universities, experiment stations, and extension services? What problems were these organizations designed to solve?

When modern American agriculture developed, this country was dominated by agriculture as a source of cultural, occupational, and economic norms. In 1890, 24.7 million Americans (42.3% of the population) lived on farms. There were 4.6 million farms with 623 million acres in production, and the average farm size was 137 acres (Albrecht and Murdock, 1990, pp. 43-44). The earlier form of agriculture practiced in America was failing. Under that system, cropland often was cleared by large-scale burning, used to produce crops for a few years, and finally used up. Cheap land encouraged this approach (Cochrane, 1993, p. 29). Most American farmers followed a "use it up and move on" approach: "So long as the continent appeared empty and cheap, very few people would worry about conservation of the soil" (Petulla, 1988, pp. 94-95). By 1890, however, Frederick Jackson Turner declared the frontier closed and civilization of the contiguous United States complete:

> 'The . . . rough conquest of the wilderness is accomplished,' he pointed out, 'and . . . the great supply of free lands which year after year has served to reinforce the democratic influences in the United States is exhausted.' Inevitably, he wondered if American ideals 'have acquired sufficient momentum to sustain themselves under conditions so radically unlike those in the days of their origin?'. (Nash, 1967, p. 147)

Thus the modern farm and its allied institutions at least in part were created with the realization that agriculture no longer was a subsistence frontier enterprise. Instead, it was time for the tools of science to be applied to increasing the productivity of American agriculture so that widespread economic prosperity could come to a largely rural America. The organizations that support modern commercial agriculture were created to generate new knowledge and to use that knowledge to solve society's problems. They were part of a complex of institutions designed to fulfill a specific mission, based on specific problems (Schuh, 1984).

In 1897, "Tama Jim" Wilson became the Secretary of Agriculture. He believed in the role of science in the future of agriculture and thus made USDA "a great science producing institution" (Cochrane, 1993, p. 104). Scientific agriculture was developed in Europe in response to predictions of Thomas Malthus that food production would have to increase to prevent the great famines that came from overpopulation (Carroll, 1990). The federal system was expanded with the organization of the experiment station system in 1887 and again in 1914 with the creation of cooperative federal/state/county agricultural extension services for demonstration and instruction. The belief was that science would end the threat of famine, produce rural economic prosperity, and make America the envy of the world.

That was the world the USDA was created to serve, but it no longer exists. In 1990 only 3.9 million Americans (1.5% of the population) lived on farms (U.S. Dept. of Commerce, 1992, p. xii). There are 2.14 million farms using 987 million acres, for an average farm size of 461 acres (U.S. Dept. of Commerce, 1992, p. 644). Agriculture no longer is the major source of employment in rural America and it no longer is the major source of income for most farm families. By 1987, the average annual cash income of farm households was higher than that of non-farm households (Hallberg, 1992, p. 78), but economic disloca-

tion of rural people to urban areas has been common for most of this century because of a lack of rural economic opportunity. Famine no longer is the problem; the problem is oversupply. Finally, scientific agriculture is no longer seen as an automatic good.

Suburban Domination

America is now dominated by the suburbs. Just as 1890, according to Turner, brought the end of the American frontier, 1990 was the first time that over half the population lived in metropolitan areas of more than one million people. Most growth in metropolitan areas since 1950 has been in the suburban ring, not the inner city. As Garreau (1991) points out, suburbia is now America's norm—the source of its cultural ideals. Nowhere is this more apparent than in California. Almost exclusively because of suburban growth since the 1950s, California has as many members of the U.S. House of Representatives as the 22 least populated states combined.

The American power base today is in the suburbs, and suburbanites are difficult to put into simple categories. Few of them, even in traditionally agricultural states, seem to have much continuing contact with rural America or commercial agriculture. As consumers, they seem to have little awareness of the linkages between food and farming. Given their affluence, they are likely to care more about food quality than economic efficiency. They are likely to see the current industrial system of agricultural production as a problem, not a solution, given its heavy use of chemical nitrogen, pesticides, and monocultures, with the resulting soil erosion, loss of soil organic matter, and water pollution (Francis, 1990).

The scientific age of agriculture has been a success, but scientists have been unable or unwilling to acknowledge the unintended problems that scientific solutions have created. To the extent that modern farmers and their allies deny or ignore these consequences—or belittle those who talk about them—their future political support is put in serious jeopardy. With government resources limited and with the political system increasingly dominated by suburbanites, science's answers to past questions will do little to insure the future of farmers, extension personnel, and public research institutions. Therefore, those of us who care about these institutions must find new and more relevant questions to answer if public support is to be expected.

Where do these societal questions come from? The answer will help us understand why agriculture is so confused about the role of science, research and social well-being.

It is difficult to see fundamental social change from the inside. However, based on the work of John Brewster, I believe that the changes the U.S. is experiencing are similar in importance and difficulty to the Protestant Reformation and the Counter Reformation of the Roman Catholic Church (Madden and Brewster, 1970, pp. 14-15). When Luther nailed his *Theses* on the church door at Wittenberg, he was not attempting to destroy the Catholic Church, only to question and reform it. When Rachel Carson wrote *Silent Spring* (1962), she was not attempting to destroy science, only to question its objectives and reform it. A century after the *Theses*, the structure of religion in Europe had changed fundamentally. Catholicism still was very powerful, but many of its institutions, such as the extensive system of monasteries and nunneries, were largely gone. A century after *Silent Spring,* science will continue to be very powerful, but will the land-grant universities, the experiment stations, the marketing cooperatives and the commodity groups still exist, or are they the monasteries of today?

People and Nature

A discussion about the future and past of agriculture is fundamentally an examination of human relationships with nature and the growing societal conflict over natural resources and public policy. Brewster, in "The Cultural Crisis in Our Times," suggested that American public policy is driven by individuals striving for personal prestige, for "assurance of significance" (Madden and Brewster, 1970, p. 10). Brewster distinguishes between *beliefs* and *values*. *Beliefs* are guides that people use in striving for significance; they are norms that individuals follow to approximate the person they wish to be. *Values* are the rankings people give to various beliefs. People can have the same beliefs but different values. Disagreements about values often are solved by policy; when people have different values they are likely to compromise. On the other hand, differences in beliefs are not easily resolved by policy, and often lead to significant public crises (Madden and Brewster, 1970, pp. 11-12). According to Brewster, beliefs are not subject to science; they cannot be proven true or false. All institutions are based on systems of beliefs and values, and are conceptualizations of ways of living that people feel obliged to follow.

In the last few years, there have been several books and conferences about the "Common Good." These discussions are similar to Brewster's idea of common beliefs. In reviewing the literature about the Common Good, I was surprised that I could not find any universal definition of it. The literature suggests processes to obtain the Common Good, but no standards by which to judge it.

I believe the U.S. is in a time of multiple definitions of the Common Good, especially as it relates to nature and natural resources. In Brewster's terms, these multiple definitions represent different beliefs; it is difficult to get people to compromise on their beliefs.

Of several conceptualizations of the Common Good, I have selected three that are important for understanding how humans relate to nature and natural resources (summarized in Figs. 1-3). I believe they contain the origins of many current conflicts about the future role of science-based agriculture and its allied institutions.

For much of the 19th and 20th centuries, the two dominant conceptualizations of the Common Good related to nature have been the Romantic and the Liberal. ("Liberal" in this context refers to philosophers such as John Locke and Adam Smith, who saw private ownership of property and minimum interference from the "Crown" as keys to a better society.) The Liberal has been more powerful, the Romantic largely reactionary.

I believe the Romantic and Liberal norms of public policy are inadequate for the challenges that face us. Much current debate on public policy and the environment can be characterized as Romanticism versus Liberalism, John Muir versus Gifford Pinchot, former Sierra Club head David Brower versus dam builder Floyd

Figure 1. Standards for the Liberal Vision of the Common Good.

Goal of Society: To create a social utopia on earth; to create public civilization via economic competition; a social utopia where all hunger, poverty, and human suffering are eliminated and all people have equal opportunity; the perfection of humans on earth.

The Defining Challenge: To create the social, political, technical, and economic mechanisms that will make utopia possible.

Major Mechanisms

- **Science**: The key to utopia. Science is the best, most efficient method of obtaining knowledge; only the knowledge that comes from science is valued.
- **Economy**: The primary mechanism for determining society's winners and losers—those who win in the economy should be leaders in other spheres; the primary mechanism for allocating resources based on efficiency; the device for creating and exchanging surpluses.
- **Elites**: The people selected by economic, intellectual, artistic, and physical competition; those who win the competition are best prepared to lead.
- **Community**: The people we compete and cooperate with in our attempt to become leaders and reach utopia.
- **Natural Resources**: The stock of existing, usually prehistoric commodities we will use in creating utopia.

Modern Forms: The multinational corporation; the military industrial complex; land-grant universities; neoconservative to Keynesian economists; economic development professionals; professional athletes.

Standards of Performance: Efficiency, current return on investment, GNP or GDP, audience size, predictability.

Key Words: Progress, growth, machine-like, "a rising tide lifts all ships."

The Liberal Vision of the Common Good: Economic growth, spurred by individual consumption and competition and led by corporate, government, and scientific elites, will ultimately solve all society's problems.

Figure 2. Standards for the Romantic Vision of the Common Good.

Goal of Society: To recognize and celebrate the heroic individual who remains true to history's original view of the pure, independent person.

The Defining Challenge: To test yourself against the frontier; to know and maintain your personal beliefs and vision in the face of the dehumanizing influence of the Scientific Revolution; to refuse to be standardized or commodified; to express your passion; to do what you know is right, regardless of cost.

Major Mechanisms

- **The Society, Clan, or Group**: The group of people, usually small, which provides motivation and support. The group is where you gain and regain strength.
- **The Leader**: The individual who helps you see your vision, your truth.
- **The Wilderness**: The place of physical or spiritual danger where you must go to find your vision, yourself.
- **Civilization**: The place where your vision is challenged, corrupted, commodified.

Modern Forms: Men's movement, especially followers of Robert Bly; paramilitary groups; some elements of radical ecofeminism, new age, animal rights, and wise use movements; certain religious cults.

Standards of Performance: Idealism, maintaining one's identity, beating the system "your way."

Key Words: THE TRUTH, self-actualization, Noble Savage, the loner, pristine wilderness.

The Romantic Vision of the Common Good: Each of us must choose between complacency and struggle. Society calls for complacency; the true individual fights standardization to uphold what is right.

Figure 3. Standards for the Ecocentric Vision of the Common Good.

Goal of Society: To live in harmony with the ecological community of which we are part; to optimize the balance between human needs and the health of the ecosystem.

The Defining Challenge: In the near term, change the human cycle of production and consumption to reduce waste and maintain the existing stock of resources of nature for the future; in the long term, humans should take responsibility for living at a scale that is not a major source of ecological disruption and disturbance.

Major Mechanisms

- **Policy**: The intentional effort by humans to sanction those incentives, disincentives, beliefs, and values intended to reduce the negative impact of humans on other parts of the ecosystem; policy is the key to articulating shared human beliefs about reducing our disruption of the planet.
- **Economy**: A mechanism for articulating incentives and disincentives that are a product of policy; a semiautomatic feedback loop that should be designed to promote ecologically acceptable behaviors while discouraging damaging ones.
- **Science**: A means of understanding how best to target incentives and disincentives; an intentional feedback mechanism which should help us understand the effects of our policies; a means of attempting to understand the inherent rationality of nature through the application of a multidisciplinary examination of nature.
- **Optimization**: The ecosocial objective of intentionally attempting to harmonize multiple processes serving multiple constituencies at multiple scales of time, scope, size, and order.
- **Nature**: The source of most norms within the ecosystem; the metaphor for how humans should organize their institutions.
- **Wilderness**: The place in nature that best demonstrates the changing, evolving norms of nature; the part of nature that is least predictable; the place we must manage in a manner that maintains its normative values.

Modern Forms: Very limited so far; intentional "low-impact" human communities; some elements of sustainable agriculture and sustainable forestry movements; some elements of ecofeminism and "simple living" movements.

Standards of Performance: Maintenance of natural rates of biological diversity, soil quality; limitation of externalities (near-zero pollution); minimum use of stock resources, maximum use of flow resources; reduce rate of consumption (declining GDP in rich nations), zero population growth.

Keywords: Nature is norm; sustainability; optimal not maximum; systems approach.

The Ecocentric Vision of the Common Good: Humans have a unique responsibility to live their collective lives in a manner that promotes the survival of all species; humans are a device that evolved on earth to increase the learning capacity of the planet; we are a feedback loop, and we must start behaving like one.

Dominy, or spotted owl versus logging jobs (Nash, 1967, pp. 128-135; McPhee, 1971, pp. 153-245). The Romantic vision of natural resources sees them as something to be preserved in a primitive state so that people will have a place to which they can return, a place to find themselves (Nash, 1967, pp. 44-65). The Liberal view holds natural resources as something to be owned and used, even if the more modern use is for hiking or other nonextractive activities (Nash, 1967, pp. 23-43). This view commodifies natural resources; they have no value except for human use.

The modern industrial farm and the land-grant system clearly are instruments of the Liberal vision of the Common Good. Beginning mainly with local and county agricultural societies in the 1820s, the push to use science and education to increase agricultural productivity has been an attempt to improve nature from the Liberal perspective. Drawing on scientific research models developed originally in Germany and England, U.S. public and private institutions have worked to increase the productivity of American farmers (Cochrane, 1993, pp. 240-247). These efforts have been highly successful (Lewontin and Berlan, 1990).

If the U.S. stays with the Liberal vision as its primary focus, most farmers, land-grant universities and related institutions will be out of business in one or two generations. Cochrane's "Treadmill of Technology" theory (1993, pp. 387-394) suggests that farmers are driven to adopt new, more efficient technology as a way of reducing costs. Those who adopt the technology first have a short-term benefit until most farmers make the shift, which wipes out the gains of early adopters. The last farmers to adopt, or those who never adopt, gradually are driven out of business, or in Cochrane's colorful language, "cannibalized." The technologically strong and fast survive and expand; the technologically weak and slow contract and die.

Is the same thing happening to public research and education institutions? I propose Stauber's "Treadmill of Declining Political Effectiveness" theory. According to this theory, public research and education institutions, blindly following the belief in increased production efficiency as a social goal (as they should, based on the Liberal view of the Common Good), help put more and more farmers out of business. As the number of farmers gets smaller and their political influence wanes, there is pressure on research and education officials to develop ever more efficient technologies, thus driving more farmers out of business, which further reduces the political base, and so on.

If the U.S. keeps the current structure and values in its science and education, I believe we will see Stauber's Treadmill slowly squeeze out the very efforts that could be revitalizing American agriculture. Increased emphasis on production efficiency through technology will eliminate many regional experiment stations that are helping farmers address local environmental problems. The system of county-level extension agents will be replaced by area-level and then state-level specialists who will work primarily via telephone, fax, and electronic mail. Ultimately, field-level extension personnel will be replaced by salespeople from the manufactured inputs sector. Land-grant universities will get out of the business of training farmers and instead will focus on the next generation of agribusiness technicians and salespeople. Research at land-grant institutions, especially the production-oriented work, increasingly will focus on the high technology, high return opportunities to increase production efficiency.

A new vision of the Common Good has been emerging for the past half century: Ecocentrism. Some would claim it began with Aldo Leopold, or more recently, Rachel Carson. It is not complete, but it forms the core of the attitudes expressed at the 1992 Earth Summit in Rio de Janeiro, and by the Green political movement in Europe and much of the environmental movement in the United States. I believe that the Ecocentric vision of the Common Good has the potential to attract a strong following among the suburban majority that will dominate American politics for the next 30 to 50 years, and that it could provide a renewed justification for a changed land-grant university system.

The social contract that has underwritten much of the public investment in science has been based on the belief of the Liberal vision of the Common Good that science can improve nature. However, the Liberal vision conflicts fundamentally with the Ecocentric vision, particularly in regard to improving nature. The Romantic vision assumed that nature could improve humans, not vice versa. The Liberal vision assumed that humans could improve nature, not vice versa. The Ecocentric vision assumes that humans are part of nature and that they can improve nature only by improving human behavior toward nature.

Growth versus Sustainability

To improve nature, humans must improve themselves. But what standards should they use for improving their relationships with nature? Can the U.S. be entering an Ecocentric phase characterized by *sustainability*, in the same way that the Liberal era focused on progress?

Our society is hooked on growth as the way to solve its problems, growth that is defined largely within the Liberal tradition. Shall economic growth be a permanent, normal process of healthy economies or a temporary state of transition? (Daly, 1980). Economics and other disciplines important for public policy must attempt to answer new questions that move beyond growth as the answer to all problems, and beyond efficiency as the best means of allocating scarce resources to promote growth. Daly (1980, p. 2) put these questions this way: "How to live on a *finite* earth? How to live a *good life* on a finite earth? How to live a good life on a finite earth *at peace and without destructive mismatches*?" (emphasis in original).

The scientific disciplines must give up their preoccupation with policies of perpetual growth if they are to deal with these questions. In the past, economic growth, supported by "good science" in the Liberal tradition, was seen as the solution to problems of distribution: tell the poor to be patient and work hard, and economic growth will solve their problems. With the end of growth, however, the problem of poverty will have to be dealt with in other ways (Daly, 1980).

For example, Adam Smith believed that personal fulfillment is led by an invisible hand to promote the Common Good. The U.S. still operates as though Smith was right, but was he? (Hardin, 1980a). Humans, wanting the infinite, have been corrupted by attempts to satisfy insatiable hunger in the material realm: "The ultimate end is sufficiency, not excess, of worldly goods" (Hardin, 1980b, p. 124). So how do humans create a moral code, a sense of the Common Good that focuses on sufficiency, not excess?

I propose that sustainability is composed of a series of basic principles or tenets:

- It requires that humans approach all major issues from the perspective of the system, rather than of a species.
- It requires that humans attempt to optimize fulfillment of various values simultaneously, rather than maximizing just one dimension.
- It assumes that knowledge is personal, essential for survival, a product of interaction, and perpetually incomplete and evolving rather than fixed or static.
- It starts with the belief that the ecosystem has its own rules that have evolved over time and that continue to develop. These rules, which people do not entirely understand, cannot be violated without adverse consequences.
- Humans hold a special place with regard to sustainability, as the only species that can and will degrade the planet. Despite this special place, however, sustainability should not be defined solely in human terms.
- The goal of sustainability is the survival and well-being of all species, not just humans.

Under the Romantic vision of the Common Good, the best humans engage in "hero thinking," and while nature can improve humans, humans can only degrade nature. This view is critical to certain elements of the environmental, Wise Use, and "Back to

Nature" movements. The Liberal vision of the Common Good has "linear thinking" as a positive social norm, under which humans can either improve or degrade nature. Production science, experiment stations, and the land-grant university system are reflections of these values. The Ecocentric vision of the Common Good still is emerging, but it seems to value "systems thinking" as the intellectual norm. It sees humans as part of nature and believes that the best way to improve nature is to improve human behavior.

Visions of the Common Good

What are the futures of agriculture? The answer depends not on science, but instead on what individuals believe and value, and on their vision of the Common Good. However, some voters do not see supporting the modern, research-oriented land-grant university as part of the Common Good. In fact, I've been told there have been discussions within the Washington State Legislature on eliminating all state funding for agricultural research and extension. That proposal, no matter how extreme, should clearly be seen as questioning the current Liberal vision of the Common Good; it is a warning that should be heeded.

Those who simply hold to the past Liberal definition will see themselves left behind and their institutions weakened and diminished. I believe the farmer, scientist, educator, advocate, and citizen all have a role in redefining the Common Good to include more than humans and in evaluating current and future needs. We need to stop defending the past and instead begin developing a future that has a different view of agriculture and the Common Good.

Regardless of one's vision of the Common Good, agriculture will survive, but farmers and ranchers may not. Science, too, will survive, but land-grant universities and related institutions may not. The U.S. is creating an evolving view of the future that encompasses much more than just how people farm; we are rethinking how humans relate to nature and their goals for the future. To create this new vision, the U.S. must have a national debate that questions its values and beliefs. I expect that such debates will be a dominant element of public discourse for the next several decades. No institution is likely to come through this period without significant change. The more rigidly an institution responds to the debate, the more likely it will suffer the fate of the monasteries and nunneries.

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Will there be people in sustainable ecosystems? Designing an educational mosaic for the 22nd century

Charles Francis and James King

Abstract. *Unlike other creatures, humans have the unique ability to delay their own extinction. We can store, analyze and transmit information to the next generations, and education helps us adapt to varied ecological situations. Looking beyond the 21st century to a post-industrial society where biological systems will emerge as the most renewable and sustainable activities on the planet, we need educational systems to prepare creative problem solvers who can confront and adapt to change and be willing to move toward lifelong growth and learning. Students need to understand the complexity of biological systems and the importance of connectedness. We need to educate them about watersheds and ecosystems, about the roles of a wide range of species and how they interact, and about long-term sustainability. Some programs already involve interactive student activities, case studies, and real world examples, and have empowered students to formulate their own approaches to challenges. A new initiative in the North Central region includes a structured experiential program in practical agroecosystem studies that taps into the technical and financial resources in the region's 12 land-grant universities and other organizations. In the future, we will need to forge more linkages between education and research, understand the impacts of alternative strategies for food production and other human needs, and search for ways to empower people to pursue their own educational agendas. This approach should include a mosaic of educational opportunities that will promote the survival of our species beyond the 22nd century.*

Key words: teaching, learning, future education systems, sustainable agriculture

The basic question is, what vision do you aspire to?—A. Maslow (quoted in Hoffman, 1988, p. 280)

In spite of what humans do or don't accomplish on this planet, nature will survive in some form. Many species already have shown their ability to use instinct and adaptation to prevail over changes in the exosphere that we humans would find difficult. The Sandhill Cranes have been migrating through Nebraska twice each year for at least nine million years. Sharks in some form have patrolled the seas even longer. If you would like to be reincarnated at some future date, choosing the body of a cockroach would be a rational decision if you would like your soul to survive for a few more generations. The notion of "Gaia" (Lovelock, 1979) — that the planet functions as a living and surviving organism — should be considered seriously as we search to understand the planet and our role in its future.

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To think about the role of humans in the future, it is useful to examine where we have been in the past. In the early 19th century, geologists explored across the depths of time. It proved to be a world without humans. In *The Immense Journey*, biologist Loren Eisely (1957, p.150) describes how the fact that

> man had not been discovered was a cause for dismay. In the man-centered universe of the time, one can appreciate the anguish of the Reverend Mr. Kirby discovering the Age of Reptiles. 'Who can think that a being of unbounded power, wisdom, and goodness, should create a world merely for the habitation of a race of monsters, without a single, rational being in it to serve and glorify him?' This is the wounded outcry of the human ego as it fails to discover its dominance among the beasts of the past. Even more tragically, it learns that the world supposedly made for its enjoyment has existed for untold eons entirely indifferent to its coming. The chill vapors of time and space are beginning to filter under the closed door of the human intellect.

The same narrow intellect participates in design of our educational systems today. Current conventional educational systems teach about an agriculture based on high inputs and generous fossil fuel use. Production systems are designed to dominate other species and the environment. We have produced enough food for many people at affordable prices, with a low fraction

of income spent on food, at least in the U.S. However, many conventional systems appear not to be sustainable, because they are environmentally unsound or unprofitable for many farmers. The overall system is not socially acceptable because of the large disparity in access to food, both among and within nations. Some argue that the food our system supplies is not nutritious, adversely affecting the health of consumers and workers, and that the system is not politically secure (Klonglan, 1992). Conventional education about current conventional food systems is not likely to produce a generation of graduates with the ability to design changes.

If education is one process by which we intend to improve the food system and to broaden the capacity of the intellect, what forms will that education take in the future? We are sure that 22nd century education will not resemble today's systems. What will these new systems do, how will they be organized, and who will be the participants? At what age will we start school? How long will students stay in school? Will there be schools?

We maintain that moving beyond the industrial model into the next century, we will encounter a biological revolution that will dominate science and agriculture. The direction this takes may determine the role, if any, that people have in future ecosystems. To move beyond the paradigm of domination of nature, and to learn to live within the obvious resource constraints that result from increasing human population and improving standard of living, humans must become highly aware, adaptable, and "educated" as a species.

We discuss a systems orientation for education for the 22nd century, using methods and examples of learning environments that are being created today, and moving on to alternative visions of the future. We conclude that today's activities involve writing the history of the future by designing a new educational mosaic, and that we can decide whether there will be people in tomorrow's sustainable ecosystems.

Systems Orientation for the Future

There is growing awareness and appreciation of the interactions and complexities inherent in agricultural systems. The inputs and outcomes from crop and animal enterprises are closely tied to the supply of renewable and fossil fuel resources, the on-farm and broader environment, and the economies of farm families and rural communities. Interactions among components in a single field or crop ecosystem include spatial interactions, as different species (crops and weeds) compete for growth resources, insects and pathogens feed on crops, fertilizers are used by the crop or leached through the soil profile, nutrients are cycled within the crops and the soil organic matter fraction in the field, and nutrients and water move between the soil and the crop or leave the system through runoff or percolation to groundwater. Interactions over time include rotation effects on pest populations and nutrient status, and cycling of elements between the organic and inorganic phases. How can we teach students about these complex interactions?

To understand dynamic systems, we must explore the importance of production inputs from outside the system, the effects of unpredictable weather, and the outputs of the system. Some of these outputs are planned, such as grain or forage for sale, while others are unintended, such as erosion, leaching of pesticide residues or nitrate, or pests that move from one field to another. There also are interactions among the enterprises or production units on each farm. The concept of "integrated farm structuring" (Francis et al., 1986) includes both spatial and temporal dimensions. In one year, the corn produced in one field may be fed to livestock in another enterprise, and manure from the feedlot may be spread on yet another field on the farm. A more subtle interaction among enterprises or fields is the decision to cultivate a particular site today, which precludes working on other fields. In a temporal sense, the cropping environment in one field is influenced by the crops chosen and the management decisions this year, which then alter the field environment for the next crop. These interactions are illustrated in a simplified way in Fig. 1 (Francis et al., 1986). Exploring farm complexities is the first step in learning how the whole farm functions as an integrated unit and how decisions on each enterprise affect the others. In designing educational systems oriented toward the future, we must ask what activities could help students begin to grapple with such complexity.

If education is focused on the outcomes of individual cropping practices, or on the success or failure of a given field or enterprise, or even on the interactions within a farm, it only begins to touch on the complexity of agricultural activities, and ignores entirely how they affect the broader community, watershed and society. Understanding how crops respond to added nutrients and knowledge of which insecticide kills which bug are important components of undergraduate education. Even more important is a systems-oriented learning that helps students understand why these inputs affect crops and what the multiple outcomes may be from each practice. If students can understand the basic principles of crop growth and development, plants' reactions to the environment, and animal nutrition and efficiency of energy conversion, they will be better prepared to face future changes in economic conditions, regulations, or goals of agriculture. Thus, we need a new educational mosaic: a mixture of activities that will help students capture the essence of current and alternative practices, the complexity of systems, and the interactions that these systems have with the broader physical, biological, and social environment. Students will need to see the long-term picture, not just the short term; they must understand the total system, not just the components. They must see beyond individual concerns to consider and act on broad societal interests (Johnson, 1990). Do today's undergraduate curricula meet this objective?

It is important to confront the issue of boundaries early in the educational process. A component approach to technologies and systems ignores the overlapping of elements, the porous nature of inter-

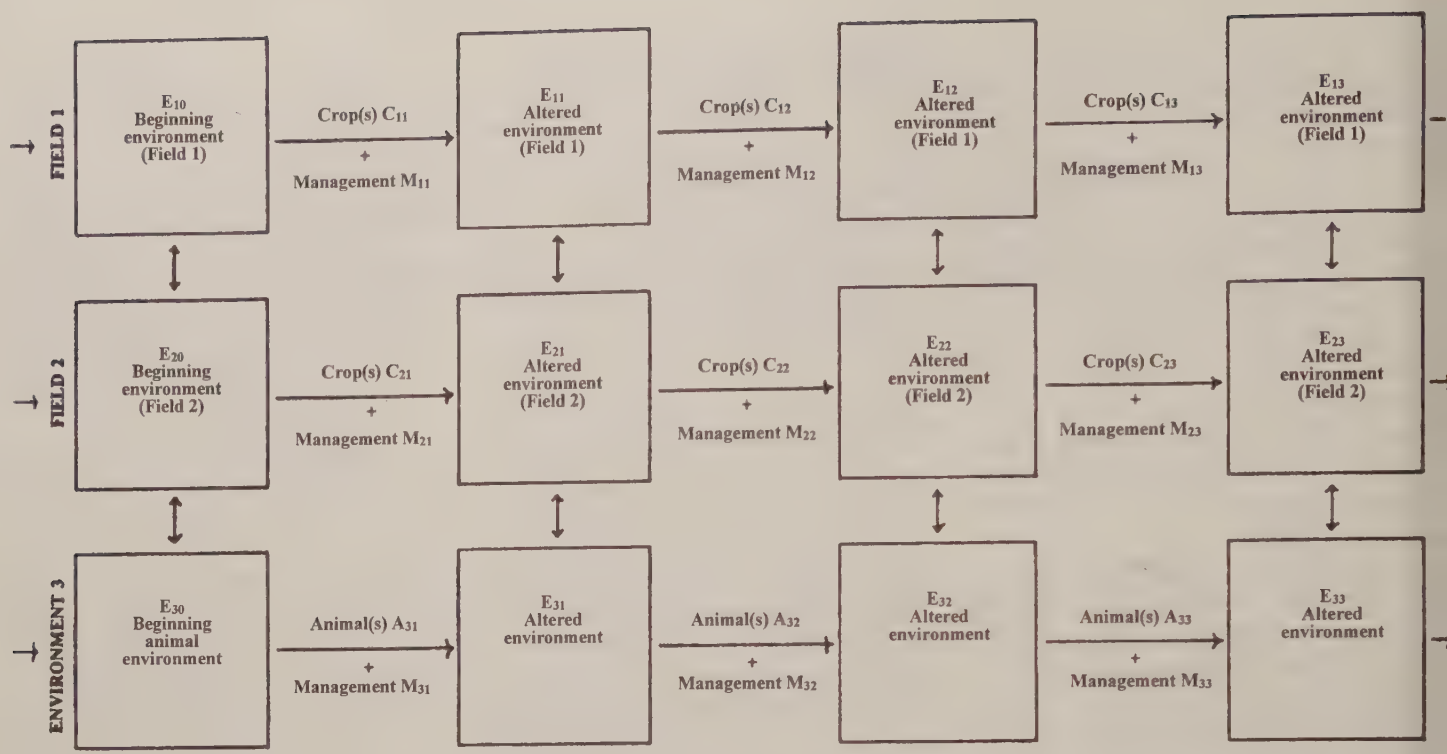
FIELD 1
FIELD 2
ENVIRONMENT 3
E10 Beginning environment (Field 1)
Crop(s) C11 + Management M11
E11 Altered environment (Field 1)
Crop(s) C12 + Management M12
E12 Altered environment (Field 1)
Crop(s) C13 + Management M13
E13 Altered environment (Field 1)
E20 Beginning environment (Field 2)
Crop(s) C21 + Management M21
E21 Altered environment (Field 2)
Crop(s) C22 + Management M22
E22 Altered environment (Field 2)
Crop(s) C23 + Management M23
E23 Altered environment (Field 2)
E30 Beginning animal environment
Animal(s) A31 + Management M31
E31 Altered environment
Animal(s) A32 + Management M32
E32 Altered environment
Animal(s) A33 + Management M33
E33 Altered environment

Figure 1. Conceptual pattern of interactions and integrations of primary crop and animal enterprises on a resource efficient farm (Francis et al., 1986).

faces, and the arbitrariness of the boundaries we draw between components or outputs of systems. A highly visual representation of the concept of fuzzy boundaries is found in the surrealist paintings of the Spanish artist Remedios Varo (Kaplan, 1989). In her early travels with an engineer father throughout North Africa, her artistic training in Spain and France, and her productive professional life in Mexico and Venezuela, Varo blurred the lines between animal and vegetable, living and non-living, and even the spiritual and material worlds. The blending of the material and spiritual worlds, now called "archology" or "ecological architecture" (Soleri, 1973), for some people is a legitimate field of serious study. Varo's blending of disparate worlds suggests the artificiality of barriers or boundaries that we construct from our limited field of vision, and leads us to think of new combinations of elements and how they fit together to form a complete picture.

In a recent program at Iowa State University, we presented an integrated approach to learning about systems, including small group discussions, audience feedback, and a range of visual approaches. While the faculty members were taking careful notes and warming to the educational process, a lone undergraduate sat in the back of the room and recorded his own unconventional notes (Fig. 2). In "Surviving a Lecture: a Non-Phenomenological Systems Analysis," his drawing captured much of the essence of our talk: many interactions, overall complexity, some dead ends, fuzzy boundaries, and cycles galore. How many students in the future will see systems in this way?

These are some issues and questions relating to systems and the design of learning environments to help students understand them. The following section summarizes some teaching techniques that have been successful so far. We recognize there is much to learn about the educational process.

Learning Environments and Educational Methods

There are likely to be great changes over the next century in the land-grant universities, and in all higher agricultural education. Regional universities will use limited available resources to educate the next generation of agricultural leaders and technologists. The undergraduate curriculum may last for six or more years to include more practical experience, interaction with farmers and food industry specialists, internships within the agricultural sector, and broader preparation in communication skills and global perspectives. Language training and international experience may become an integral part of undergraduate education. It is likely that college will not start until later, with a two-year national service obligation coming before the undergraduate experience. Although we cannot predict with certainty the format of this education, it is possible to outline some types of educational methods and experiences that will be used. The history of the future is being developed today as educators try innovative approaches around the world.

Presentations are likely to shift from lectures and carefully engineered exercises to more participatory and open-ended educational experiences. Already we are seeing examples: higher order thinking (Resnick and Klopfer, 1989; Pressley et al., 1990),

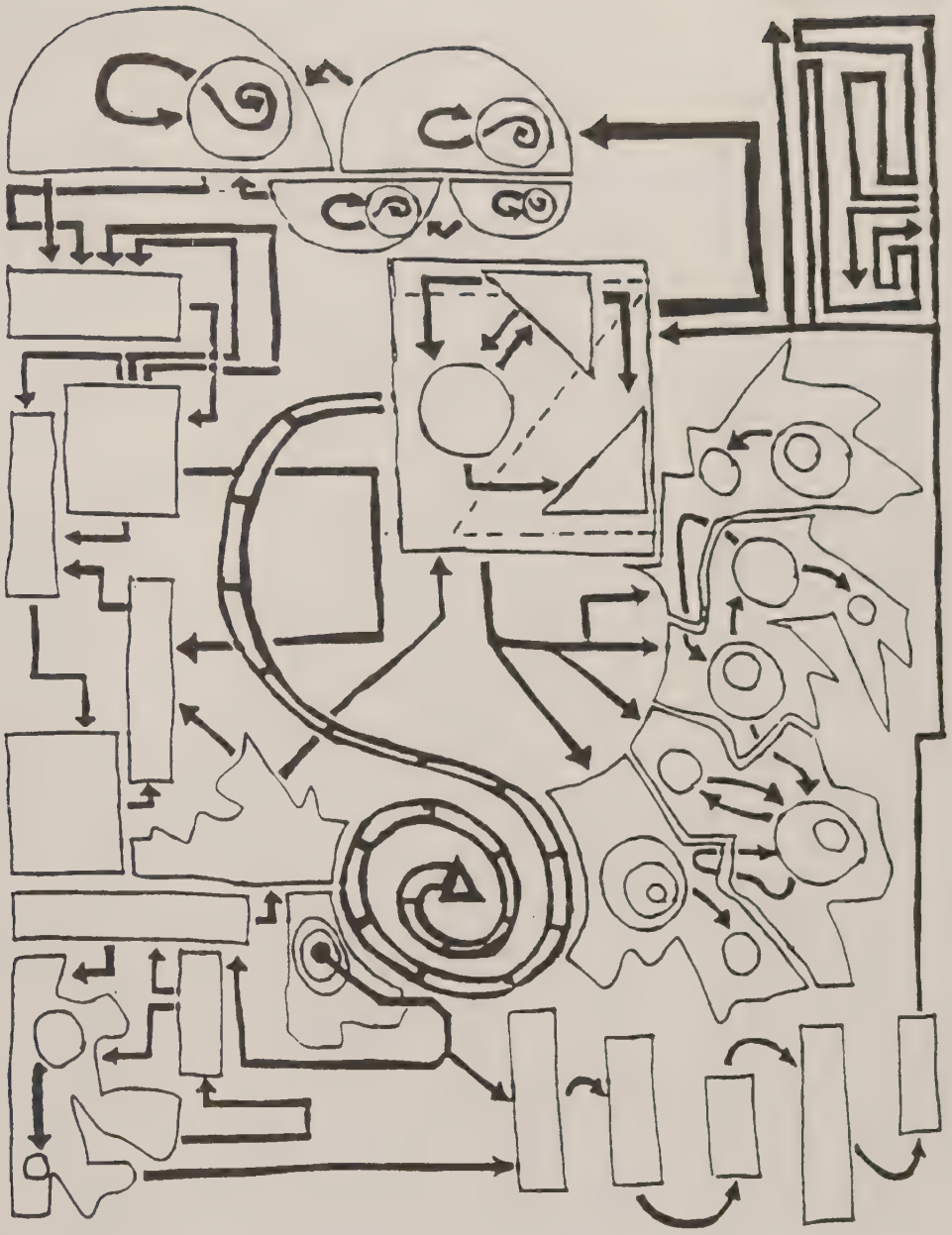

Figure 2. Surviving a lecture: a non-phenomenological systems analysis (K. Francis, 1993).

active learning (Bonwell and Eison, 1991), interactive games (Krinke et al., 1992), contextual learning (Kinnaman, 1993), computer conferencing (Coombs, 1992), interactive satellite delivery (Salvador et al., 1993), learning assessment (AAHE Assessment Forum, 1992), and joint planning meetings (Lev et al., 1993).

Creative and participatory media will be used much more often. Use of computers, videos, and simulations now can provide students with an extended time experience that would be impossible when teaching plant breeding or crop rotations empirically. These techniques appear to "motivate students by appealing to their curiosity and creativity. Incorporating new technologies in course work also exposes students to communication and research tools that may be important in their careers" (Michaels, 1993, p. 100). Likewise, computer games and economic simulations can be used to teach management skills and decision making in agriculture. An example is the AgVenture computer program developed at Oregon State University (Cross, 1993).

Case studies are becoming an accepted method for incorporating real-life complexities into teaching about decision making. In "The Worth of a Sparrow," University of Minnesota faculty provide a case that "provides a focus for consideration of research methods, interest group agenda, and the role of the university in representing the public and performing its re-

sponsibilities" (Crookston et al., 1993, p. 134).

Another practical approach to involving students with the real world is the on-farm survey and interview process that evaluates soil potentials, pest problems, irrigation needs, economic situation, marketing approach, and overall goals of a farm family (Mason, 1991). Students complete a farm management plan that is reviewed by both the instructor and the farmer. Students "improved their abilities to recognize problems, integrate knowledge, evaluate production practices, and recognize the importance of personal and family goals." (Mason, 1991, p. 19) These examples illustrate the participatory approaches that faculty members are using today to involve students in the educational process more actively and in more open-ended ways. These efforts go beyond the now fashionable "problem solving" that solves current challenges but does not anticipate future needs. The new approaches help people look inward at their own behaviors and learning styles; as a result they learn how to learn and how to change (Argyris, 1991).

The importance of independent study needs to be addressed. Cox (1993) reviewed recent surveys and writings about individual student projects, and concluded that independent study was one of the best ways to encourage habits and capacities leading to lifelong learning. The undergraduate independent research project and thesis are components of many liberal arts colleges and are found in some honors programs in the land grant universities. They help students learn to approach problems, use the literature, and develop a capacity for independent work. It also is good preparation for graduate study. However, we should question whether the individual project is the best focus for a future-oriented educational program. In the 22nd century, work often will be done in interdisciplinary teams. Success will depend on communication and cooperation with others. Team projects and learning could evolve by building on the success of independent study. A team research activity could be a valuable and logical extension of the group discussions and interactive projects that are fast becoming part of innovative undergraduate curricula.

Greater participation is equally important for adult learning. Extension meetings have often been organized as lectures or formal presentations with slides, transparencies, or videos that put the audience in a passive mood. Individual exercises, small group discussions, farmer panels, and active field tours and demonstrations get farmers' attention better and stimulate more active participation. A recent session on grain sorghum planting density used a one-page survey for farmers to summarize their own practices and decision making. The survey was followed by a facilitated discussion of what they were doing and why. University research results were brought in to illustrate some principles and to support the farmer observations that came out during the meeting. However, they were not held up as the answer, and farmer experience and data were given high credibility.

Another workshop on successful farm management was organized and conducted by an agronomist/economist team in Nebraska that explored flexible options in the farm program, the importance of record keeping, and the design of diversified farmscapes for the future. The presenters acted as facilitators, leading the farmers and consultants through the topic and building on the experience of the group. Each one-hour session included a brief evaluation of what was learned, what questions remained unanswered, and other relevant comments from the group. This series of workshops has stimulated requests for similar learning activities in five additional sites during the winter extension season.

Participation must also occur during the planning process. Lev et al. (1993) provide three interesting models of farmer-scientist interaction during planning. Farmers, agribusiness people, and consumers must be part of the teaching faculty. They, along with students, must be part of the new curriculum design team. Participation must be broadly based and "organizationally deep" if it is to succeed.

To create effective learning environments will require new or drastically modified facilities. The lecture-style classroom will evolve into "classspace," modified to allow the multi-media equipment and linkages that are now available. We need chairs and small tables, walls that can be written on and serve as projection surfaces, and the ability to organize and reorganize quickly for specific activities. A classpace with multi-way video equipment will allow sending the presentations to multiple sites and receiving downlinks from remote locations. Faculty will include farmers, industry leaders, consultants, consumers, and others who can be brought into the classroom to interact with students. The classroom may open onto a field or greenhouse where plants are immediately available for observation or manipulation.

Much of this potential for a challenging, hands-on learning environment can be realized without the budget of an EPCOT Center or a Biosphere II, but by using some ideas that have been developed in these innovative projects (Knuth, 1987; Kelly, 1992). Creation of exciting learning environments and the innovative methods that will be used in them may require serious reallocation of current budgets and facilities, and new thinking about education and learning. Although there are trailblazing pieces of the solution in our colleges and universities (King, 1993), there is little indication that major thought is going into how we can study ecosystems in the future.

One promising initiative is the North Central Institute for Sustainable Systems, an informal consortium of futurists who are planning a regional educational activity. This program will pool the collective energies of several university faculties and include farmers and other agricultural specialists as part of the regional cadre of teachers. The objectives of this "purpose-centered system of education" (the term is from Cohen, 1993) will be to combine classroom learning with real world experience on integrated agricultural systems as undergraduates move through their basic chemistry, biology, and humanities courses; to stimulate communication skills and provide opportunities for group projects and learning; and to bring together faculty and farmer expertise on agroecosystems from around the region to benefit undergraduates interested in sustainable development. Through the entire four-year program, students will have at least one special class or seminar each term that will bring them together to work on integration of concepts and practices. They will spend summers in practical intern-

ships living and working on farms and learning about rural community economies and dynamics. A season-long on-farm research experience will culminate in a senior thesis or project to hone communication skills further. This program of regional sharing is viewed as a possible model for redirecting undergraduate education toward agricultural systems. These are some programs and ideas of today that are oriented toward the future.

Alternative Visions of the Future

Underpinning today's future-oriented education is the assumption of challenging change itself. As Sheingold (1991) notes, faculty members themselves "will have to confront squarely the difficult problem of creating a school environment that is fundamentally different from the one that they themselves have experienced" (p. 23). Faculty will need new images of education. How they think about the future and about thinking is extremely important.

There are two approaches to envision the future of agricultural systems: extrapolating from today's systems and fine-tuning them with improved technologies and judicious use of natural resources to make agriculture more efficient, profitable, and environmentally sound; or a well-designed projection of what would be most desirable in the future, and a carefully designed structure of agricultural ecosystems to meet these human goals.

The first approach suggests an acceptance of today's educational systems, the present structure of agriculture, current trends toward larger and more specialized farms, and thoughtful adjustment of the status quo. Such an approach would buy time as we confront an increasing global demand for food and growing concern about how agriculture affects the environment and available resources. Most people involved in sustainable agriculture today are following this route.

The second approach suggests a complete reevaluation of the direction, the objectives, and the role of humans in future ecosystems. It requires much more thought, raises multiple challenges to today's institutions and human goals, and makes us follow a difficult road to consensus on the future. With either approach, decisions must be reached rapidly on managing the size of the population and on rational conservation and judicious use of the planet's non-renewable natural resources.

The extrapolation and fine tuning model that we currently pursue will catalyze some important changes in the future (Edwards, 1987). Reducing fertilizer and pesticide application rates will help reduce production costs and lessen the environmental damage caused by current farming systems. Ridge planting, zero tillage, and other modified soil management practices are current practices that reduce erosion and lengthen the productive life of many soils. Additional innovative methods are needed. Planting windbreaks, constructing terraces, and using more rotations and legumes all can contribute to more efficient resource use and more profitable production of cash grain crops and livestock.

Increased use of the products of biotechnology can contribute to the sustainability of production systems, especially if these benefits are incorporated into new cultivars with greater pest tolerance, ability to withstand stress, or more efficient nutrient use. These new practices and technologies will help agriculture combine the benefits of industrialization with the new ability to manipulate specific crops and animal species. We can learn how to introduce these innovations so that farming can be efficient and profitable, and so that farmers and rural communities can survive through the next century. It will be important to study how the benefits of these new technologies are distributed to insure that food production can be maintained or increased, and to maintain rural areas as desirable places to live. Educational systems can meet the demands of this model by including courses and seminars on sustainable agriculture, rural development, and ethics and values, and by integrating these concepts into existing courses. This is the current path that most of us pursue.

An alternative and more futuristic plan is to pursue the study of ecosystems, develop an understanding of the complexities and interactions among plants, humans, other animals and the natural environment, and arrive at consensus on the future role of humans in these ecosystems. Such an approach would require challenging our current economic systems and patterns of land and resource ownership. It suggests reconsidering how we divide the rewards of labor, exploring the potentials of "zero base" wealth and resource use (periodic redistribution), and managing our human population to reflect the long-term carrying capacity of the earth. It also will force us to devise structural economic innovations (Didsbury, 1993, p. xii). We need to include quality of life indicators and feminist economics, and challenge the impact of religious beliefs on long-term sustainability of the global society.

A short-term but logical starting point would be to use Native American philosophy to examine the impacts of seven previous generations on today's environment, and projecting the impact of alternative decisions seven generations into the future. Eastern traditions, such as Buddhism, may offer thoughtful approaches through meditative, pragmatic insight (Varela et al., 1991). A futuristic approach would move us from a focus on teaching to a focus on learning. Students would come first — we will seek ways to help them remember and retain information, develop their skills for deducing solutions, provide opportunities to practice, review, and study, and challenge them to discover and uncover principles and concepts. The future will demand new interpretations of old rules (Barone, 1993).

A consensus on the role of humans in the natural ecosystem will require long discussion, ability to compromise on some religious and philosophical issues, and adherence to principles of ecology and the need for long-term survival. The educational system needed to foster such a consensus has scarcely been thought about, much less designed. Managing complexity will be essential; skills needed for the information society must rapidly evolve. The context for learning will be considered. The process of studying will change in much the same way as the content will have changed. Each student will be a prime actor; active learning in class will be the norm, and on-farm activities and internships will be more common. Competence will be shown by higher-order, critical thinking, oriented to solving problems.

Given the urgency of the global population and resource crisis, the increasing competition for scarce space and non-renewable resources, and the greater global interdependence, we maintain that the only

solution is to initiate a process that can help us design the future. It is too important to allow it to "just happen." An educational system for the 22nd century, a new mosaic, can help us move from the industrial society, through the revolutions of biotechnology and sustainable agriculture, into a future that focuses on the ecosystem. Our next generations need to understand the basics of biology, physical sciences, and agriculture. To be fully empowered, they also need communication skills, appreciation of history and human thought, and tools for working together. These individuals and teams should emerge from the first stages of this education ready to challenge the biases and directions of our current system, while maintaining a positive outlook for the future. They need to be convinced of the importance of lifelong growth and learning.

It will be imperative that students understand, function, and make decisions within the big picture. Whether we can carry out such an educational mosaic or system will likely determine whether there are people in the ecosystems of the future.

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Institutional issues and strategies for sustainable agriculture: View from within the land-grant university

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Abstract. *Sustainable agricultural research and education have gained acceptability within the land-grant system, but they still must be fully integrated into its fabric. Challenges remain in three key areas: knowledge generation, research and education, and funding. New biological and ecological knowledge is needed on plant-animal-human-environment interactions from the microbial level on upward so that we can move beyond anecdotal evidence of biological integration efficiencies to scientific understanding of the underlying processes and opportunities for human intervention. Socioeconomic research must address human motivations to change farming methods and the likely impacts of these changes on farmers, consumers, other species, and the quality of the environment.*

Generating this knowledge will affect the integration of research and education. Having farmers set the research and outreach agenda dissolves the old distinction between research and extension. This situation is complicated by budgetary stress and uncertainty about the dividing line between public and private responsibilities. The funding of sustainable agriculture creates a dilemma. Earmarked funding has helped legitimize sustainable agriculture in the land-grant university, but if it fails to become integrated into the routine land-grant research and education agenda, it will lose its newly gained momentum in the event those funds disappear.

Key words: sustainable agricultural research funding, extension, integration, on-farm research

Introduction

When considering the land-grant universities' contribution to sustainable agriculture research, extension, and education, one must be impressed by how much has changed. A decade ago, sustainable agriculture was unacceptable in many universities. Those who chose to pursue such a mission often were considered part of a fringe element doing nonscientific or irrelevant work.

Those attitudes began to change because of several external forces. First, in the late 1970s and early 1980s sustainable agriculture advocates and populists worked to place sustainable agriculture issues on the land-grant agenda. Their efforts were accelerated by the "farm crisis" of this period, when many farmers had exceptionally low income and the future of the family farm appeared in jeopardy. Farm groups and political leaders began to approach the land-grant universities asking that some research directed at enhancing yields be redirected to reducing production costs. Also, farmer stewardship groups and key farmer leaders who were experimenting with more environmentally friendly practices were approaching their land-grant universities with requests for scientific analysis of their farming systems. Still other farm groups were concerned that lower pesticide levels were needed to insure the safety of farmworkers and to reduce residue levels in consumer foods, a demand increasingly being reflected in the market. These growers wanted land-grant assistance in meeting these needs profitably. The need to change agricultural practices received a further prod in the late 1980s from studies detecting the presence of agricultural chemicals in well water (Hallberg, 1989).

The cost-price squeeze probably did the most to raise the legitimacy of addressing sustainable agriculture problems. However, the availability of funds also was a crucial factor. When funds began to be available through the Low Input Sustainable Agriculture (LISA) program of the U.S. Department of Agriculture, many faculty members and university administrators decided that sustainable agriculture was an acceptable pursuit. However, the funding was not really available until 1988; moreover, it was (and still is) modest.

Despite these legitimizing events, there remains a tension in the land-grant system regarding sustainable agriculture. For example, a chorus of critical comments accompanied the release of the National Research Council's report *Alternative Agriculture* (1989). Regardless of whether the report or the criticism was more valid, the

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intensity and the speed of the response suggests that although sustainable agriculture has achieved some acceptability in the land-grant system, it is far from being integrated into it. This lack of integration also was evident in the strategic plan for the 1990s issued by the Experiment Station Committee on Organization and Policy (1990). The plan designates food safety and water quality as the top priority research areas, but nowhere does the report specifically mention "sustainable agriculture." Clearly, sustainable agriculture is not treated like other research or extension issues.

Sustainable agriculture appears to have been less readily accepted in extension than in research circles. Many extension agents still regard it as irrelevant or even in conflict with their expertise. If so, such opinions are understandable. Sustainable agriculture means change, and change often devalues older expertise. Also, the increasing role of farmer participation in sustainable agriculture extension and its multidisciplinary nature can erode existing power and support relationships developed over a career. Finally, although scientific knowledge about sustainable agriculture issues is increasing, it remains limited. Thus academics—including extension academics—may have both a motivation to resist sustainable agriculture and legitimate scientific grounds for doing so.

Therefore, despite the impressive inroads sustainable agriculture issues have made within the land-grant system, they are far from being integrated into its fabric. Without such integration, sustainable agriculture within the land-grant colleges will remain fragile, and could easily lose momentum if earmarked funding no longer is available. Without funds specifically allocated for it, will experiment station and extension directors view it as worthy of hard funding and positions?

The remainder of this paper will address this challenge of integration within the land-grant system. Specifically, we will examine goals for integrating knowledge generation, the process of integrating extension and research, and the need for integrating funding sources.

Integration of Knowledge Generation

Sustainable agriculture is systems-oriented, applied, and multidisciplinary. As such, it provides challenges to the disciplinary basis on which universities are organized. Not just biological-ecological systems but also economic-social systems must be understood in an integrated fashion.

Over the past two decades, evidence has accumulated that sustainable agricultural practices can be preferable to conventional ones according to various criteria, including stability of yields, profitability, soil conservation, and chemical leaching and runoff (Lockeretz et al., 1981; Harwood, 1985). Our observations remain largely anecdotal, however. They tend to be based on comparisons of different farms (under different managers) or the same farm at different times. Paired comparisons do not usually delve into the underlying processes responsible for the observed differences in outputs. The anecdotal nature of the evidence has been an impediment both to increased adoption of sustainable agricultural practices by farmers and to their widespread endorsement in the land-grant community. Scientists know the precise biochemical mode of action that makes sulfonyl urea herbicides kill weeds in wheat, but they do not know why crop rotations raise yields by more than can be explained solely by leguminous nitrogen fixation (Crookston, 1984).

The challenge in generating sustainable agriculture knowledge is to integrate our understanding of various biological and social system components and to comprehend better the behavior of the systems themselves. The goal is to be able to manage plant and animal communities in a way that can be sustained both biologically in the natural environment and socioeconomically in the human environment.

The biological and ecological research agenda covers the many plant-animal-human-environment interactions from the microbial level on upward. What are the integration efficiencies present in complex plant systems (Harwood, 1985, 1993), and how do they work? How is nitrogen transformed, and how does it move in the soil, plants, water and air? How are agricultural chemicals metabolized, how toxic are the metabolites, and how stable and leachable are they? Under what conditions is conservation tillage compatible with zero or low herbicide use? What determines how long it takes to convert a conventional, energy-intensive farming system to a more sustainable one that greatly reduces our dependence on imported energy?

Frequently forgotten in research on sustainable agricultural systems is that human behavior is the key to change (Nowak, 1992). A fundamental question that must be answered if change is to occur is: "Why do farmers farm the way they do?" What are the barriers to the adoption of alternative farming systems: ignorance, constraints on time or money, technology limitations, ownership arrangements, community preferences, farm structure, public policy incentives, or family-related constraints? If behavior is to be changed through education, regulation or incentives, we must understand the complex interactions among the factors that influence human behavior.

As with biological processes, system interactions are at the heart of the socioeconomic research agenda for sustainable agriculture. Few would dispute that people have multiple goals, but how do farmers manage them? How could they manage them better? Profitability is clearly a key to the adoption of sustainable agriculture practices, but other goals matter too. How do people, and farmers in particular, value environmental benefits? What determines how consumers respond to products that differ in how they were produced rather than in what they contain (toxic residues or nutrients, for example)?

Furthermore, the desirability of alternative systems will require information on their impacts in a wide range of areas: comparative advantage; trade; prices; profits; communities; the scale, ownership, and composition of the agriculture sector; technology innovation and choices; environmental quality; and risks to ecosystems, wildlife, and human health. A question always relevant in policy formulation is: Who are the beneficiaries and who bears the costs? If changed policy is needed to obtain changed farming systems, we will need more insight on the ultimate impacts of a successful change. These impacts may be far-reaching, affecting not only agricultural ecosystems, but also the number and

kinds of jobs in the input-supply industry, the future of rural towns, the price of food, our ability to feed the earth's burgeoning human population, and the balance of agricultural trade.

Building the systems-oriented knowledge needed to advance sustainable agriculture will require close collaboration among different kinds of scientists and practitioners. However, this does not necessarily imply a need for a new breed of generalist. Greater promise for scientific advance continues to lie in traditional disciplinary excellence complemented by strong communication abilities and broad interests. The gains from specialization, as all economists know, are only captured with trade. Thus disciplinarians must trade their knowledge if society is to gain from the generation of knowledge. For the teaching agenda of the land-grant university, we still must train specialized scientists, while acquainting them with a systems perspective, involving them in applied problems early, and teaching them the listening and collaboration skills necessary for team problem-solving.

Integration of Extension and Research

If interdisciplinary collaboration includes only scientists, it will not be adequate to meet the challenges of integrating knowledge in the way just described. Research and extension must be integrated too. The pursuit of disciplinary excellence by researchers too often has meant that the research problems of farmers are ignored. Ironically, after a decade of prescribing integrated, farmer-driven research and extension as part of farming systems international aid projects (Shaner et al., 1982), land-grant faculty members are discovering that we scarcely have been practicing what we preached. This omission is being corrected, however, with the increase in participatory on-farm research and education, including farmer-initiated research and demonstration trials (Clement, 1992). The land-grant universities vary considerably in their level of involvement. Two that stand out as leaders are Iowa State University's state-funded Leopold Center for Sustainable Agriculture, and the University of Wisconsin, with that state's many local sustainable agriculture networks and well-established integrated cropping systems trials (Lakeland Agricultural Complex and Arlington Research Station, 1992).

The need for continuing this integrated research and extension is acute. Many sustainable agricultural practices involve ecological systems that cannot be established within an experimental plot. Instead, they require whole fields or field-length strips, which may be difficult to obtain on agricultural experiment stations. Even if the land is available on-station, technology is adopted more rapidly when potential adopters are allowed to do their own on-farm experimentation and demonstrations. This integration is becoming more common under the auspices of sustainable agriculture farmer associations around the country.

We conducted an informal survey of sustainable agriculture farmer organizations and their supporters in six midwestern states to learn about farmer-initiated on-farm research and demonstration trials. We found that from 1989 to 1993, the aggregate number of trials nearly doubled in Illinois, Indiana, Iowa, Michigan, Minnesota and Wisconsin (Table 1). These data substantially underestimate the true numbers, we believe, since they include only trials that were formally registered with an organization, usually to receive cost sharing funds. Moreover, they exclude federal cost sharing programs, such as for practices that improve water quality, as authorized under the Food, Agriculture, Conservation and Trade Act of 1990.

Farmer-initiated research and demonstrations raise new challenges for land-grant extension and research staff. Comparing one integrated system with another does not allow the kind of statistical comparison that most researchers were trained to conduct. Field-scale experiments may not be sufficiently replicated to offer the number of degrees of freedom needed for some statistical tests. Especially when there are few replications, uncontrolled variability in management and resource quality may confound comparisons between different farms.

These can be daunting problems at first. However, in the case of the Michigan Agricultural Stewardship Association, farmers engaged in their own research quickly realized the value of replicated trials and careful experimental design. As a result, they came to their land-grant university for assistance. One consequence has been that on-farm, farmer-managed experiments have been started that have comparable validity to those of experiment station research. Such experience is common in only a few states, however. In most states, researchers and extension specialists have not yet accepted the challenge of collaborating with farmers in designing farmer-managed experiments.

Perfect integration of extension and research occurs when researchers extend their own work and extension specialists conduct their own research. There are

Table 1. Farmer-initiated on-farm trials reported by farmer associations and state programs, six midwestern states, 1989-93.

	Number of trials each year				
State	1989	1990	1991	1992	1993
Illinois	12	20	38	45	70
Indiana	0	10	10	10	10
Iowa	59	61	68	60	60
Michigan	0	0	15	26	28
Minnesota	161	158	123	51	31
Wisconsin	20	27	117	149	253
Total	252	276	371	341	452

Source: See acknowledgments.

many notable examples of such arrangements, but to expect everyone to be successful at both missions is too optimistic and denies most people's comparative advantages. Specialization raises the issue of incentives. Researchers may fear that the results of on-farm trials may be unaccepted (that is, "not publishable") in the scientific community. Extension specialists may fear losing control of their programs because of the multidisciplinary aspects of the issue.

But these potential threats can become opportunities; the farmer who turns to the university for assistance in research design allows academics to counter the widening public distrust of scientists and the suspicion that land-grant scientists are too strongly committed to industrial-style agriculture (Batie, 1992). By helping to design on-farm trials, the issues-oriented extension specialist can overturn the stereotype of extension agent as an "agriculture industry apologist."

Farmer/scientist focus sessions at Oregon State University offer an innovative model for future farmer-initiated collaboration with land-grant universities, with farmers setting meeting agendas and discussing land-grant research priorities with extension and research personnel (McGrath et al., 1992). The sessions provide a forum for direct communication of what different participants are doing and an opportunity to debate short- and long-term priorities. Farmers do not necessarily have more answers or vision than researchers or extension specialists (or vice versa), but each group can learn from the other.

The spread of sustainable agricultural practices that replace physical inputs, such as pesticides or fertilizers, with knowledge about the biological system (Lockeretz, 1991) raises related questions about the division between public and private responsibilities in information delivery. Knowledge-intensive technology requires data that is specific to the particular farm. Although extension offices occasionally offer soil testing, pest scouting, and related services, such tailored services overreach the traditional purview of extension specialists. Increasingly, they are being offered by private consultants. On the research side, land-grant faculty have made significant contributions to decision-support software that relies on this kind of detailed data, but the professional incentives to maintain such software are weak (King et al., 1993). As land-grant faculties grapple with how to handle these new tasks within their old roles, the need to redefine the public-private boundary becomes clear. With that need comes a set of new questions: How can cash-starved extension programs train farmers to use knowledge-intensive systems? Should land-grant extension programs redefine their mission to become intermediaries who train consultants who will teach farmers? Should land-grant researchers divorce themselves from maintaining the software they develop? If so, how can they protect the integrity of the original product?

The research-extension linkage we are advocating here will be needed for exploring a host of additional issues. Two important ones are the off-farm social and economic effects of sustainable agriculture practices (Anderson and Lockeretz, 1992), and how reduced trade regulation will affect the adoption of sustainable agricultural systems.

Integration of Funding

The kind of funding available to research and extension programs will be critical in determining how well land-grant institutions can meet these challenges. The legitimacy that federal funding has conferred on sustainable agriculture is clearly a boon in the short run, with earmarked funds catalyzing change in the land-grant research and extension agendas. The LISA program and state energy overcharge monies have led the way, and now are being augmented by fertilizer taxes in Iowa. New funds from private sources such as the W.K. Kellogg Foundation's Integrated Food and Farming Systems program may push the change farther and faster into the realm of local initiatives. But unless sustainable agriculture becomes integrated into mainstream agricultural research, that change will be short-lived. Perhaps a valid model is integrated pest management, which seems to have made the transition and now is in the mainstream.

A continuing danger is that administrators will adopt the rhetoric of sustainable agriculture without the substance. Many land-grant administrators and faculty resist focusing on the process of sustainable agriculture, instead asking narrowly once-and-for-all questions such as "Is it profitable?" or "Does it work?" Thus, if sustainable agriculture loses its earmarked funding, it is highly likely to be replaced by conventional research.

In principle, there should be a continuum between funding of participatory, multidisciplinary research, such as the Sustainable Agriculture Research and Education program (SARE, as LISA was renamed) and the disciplinary, reductionist research funding exemplified by the USDA's National Research Initiative (NRI) and the National Science Foundation. Neither extreme is unscientific, and it is false to contrast "doing research right" with "doing the right research." Still, it is a challenge to integrate sustainable agriculture with other research without its losing its unique character and focus.

Specific changes in funding could make current sustainable agriculture research and outreach efforts more appropriate. First, more SARE funds are needed. Congressional appropriations for SARE continue to lag far behind the authorization levels, although it is encouraging that authorization continues to rise, most recently from $6.8 million in fiscal 1993 to $7.4 million in fiscal 1994. Second, most agricultural research grants are for too short a time. This weakness is especially surprising in the SARE program. With a maximum of two years, these grants fail to meet the need for long-term research inherent in the dynamic nature of sustainable agriculture. Third, sustainable agriculture research must be allowed under mainstream competitive agricultural research programs. This change has only just begun to happen. The 1994 NRI call for proposals includes a new heading for "Agricultural Systems," for which an estimated $2 million will be allocated. But Congress did not appropriate funds for this; USDA is reallocating them internally. Therefore, while we see encouraging change, true integration into the mainstream of research funding is only just beginning.

Conclusions

Sustainable agriculture has come a long way in the land-grant system, but the gains are tenuous. The system can easily lose sustainable agriculture issues from its agenda and its funding. This outcome would be a serious loss. Sustainable agriculture challenges basic and applied science and education in ways that the land-grant university historically is well equipped to address. With land-grant universities reexamining their role in public education and research, sustainable agriculture provides an agenda for generating systems-oriented knowledge and integrating research with extension. The task ahead is for the land-grant universities to continue integrating sustainable agriculture into their mainstream agenda while remaining faithful to its principles.

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SARE Annual Report Features 16 Research Projects

SARE 1994 Project Highlights, the eight-page annual report of the SARE program, features descriptions of 12 research projects, and four projects that "seek answers to questions that go beyond bushels and bottom lines" by exploring how farmers and rural citizens live. Among the 12 research projects described are those which study pre-sidedress nitrate tests to reduce nitrogen rates, ways to make rotational grazing more profitable for dairy farmers, an undercutter that kills cover crops without herbicides, organic pest-control for sweetpotato whiteflies, and the use of fodder radish to control cyst nematodes in sugarbeets. Among the other projects highlighted are two which examine the barriers that keep sustainable agriculture from catching on in the South, and the ways in which wetlands help make agriculture more sustainable. Like the 1993 annual report last year, the 1994 SARE annual report was printed by *New Farm* and appears as the centerfold of the May issue of the magazine, which has a monthly circulation of approximately 46,000.

For a copy of the annual report, contact the communications official of the nearest regional SARE office: West — Kristin Kelleher, Davis, CA, (916)752-5987; North Central — Lisa Jasa, Lincoln, NE, (402)472-7081; South — Gwen Roland, Griffin, GA, (404)412-4788; Northeast — Beth Holtzman, Burlington, VT, (802)656-0554.

What non-land-grant researchers can contribute to agricultural sustainability

William Lockeretz

Abstract. *Research on agricultural production has been largely the domain of an institutional system established especially for the purpose. However, the complexities and diverse character of agriculture require diversified modes of research. Such a strategy might be better pursued by a more diversified set of research institutions. Non-land-grant institutions, although lacking the land-grant system's strong experience in agriculture and its close ties with farmers, potentially represent a large pool of scientific expertise in a broad range of fields relevant to agriculture. Also, they are under different institutional constraints, and may be in a better position to do more speculative, long-range research that does not promise immediate practical benefits. Although such research has been criticized by people in the sustainable agriculture movement who believe that research should be more directed at farmers' current problems, a truly sustainable agriculture will require a deeper grasp of how agricultural systems work. Achieving this will demand a breadth of understanding that extends beyond the production-oriented studies that dominate current sustainable agriculture research programs.*

Key words: land-grant system, sustainable agriculture, agricultural research, applied research, on-farm research

The Isolation of the Study of Agriculture

When we as nation made a major commitment to public agricultural teaching, research, and extension in the late 19th and early 20th centuries, we did so through a newly created institutional system devoted exclusively to those tasks. Consequently, agriculture was given its own colleges, its own experimental facilities, and its own system for continuing education.

No doubt, the decision to establish a new structure dedicated to these tasks made sense at the time. The needs were great, and the strong trend toward industrialization and urbanization probably would have left agriculture far behind if it hadn't been given this special attention and the protected status that came with it. Agriculture has many unique characteristics, and it is appropriate to study it in ways that recognize those characteristics. Beyond question, the nation was rewarded handsomely for its foresight in giving such high priority to the development and spreading of agricultural knowledge.

However, putting these activities into their own institutions also entailed a cost, it isolated agricultural research and education from other currents of American thought, to the detriment of both sides. Any boundary separating agriculture from everything else is artificial; agriculture and its people strongly influence and are influenced by outside forces whether physical, biological, social, political, or economic. Our knowledge of agriculture is incomplete if it is restricted to what goes on within such a boundary. This has always been true, but it is especially true today when so many farmers also have off-farm jobs, when so many of their production inputs come from outside agriculture, when their economic well-being is so closely coupled to national policies and macroeconomic conditions, and when most of what they produce passes through so many shipping, processing and distribution facilities before reaching the consumer. The shortcomings of drawing a sharp line between agriculture and nonagriculture are especially apparent when we consider agriculture's consumption of finite nonagricultural resources such as fossil fuel, and its potential for environmental damage that extends well beyond the farm's border. Similarly, one cannot draw an absolute boundary between agricultural and nonagricultural knowledge.

Unfortunately, the withdrawal of agricultural studies into an "island empire" (Mayer and Mayer, 1974) has been welcomed by the mainland as well. Universities and research institutions that were not involved in agricultural research and teaching were content to see their agricultural counterparts given a near monopoly on anything agricultural. (A large and growing sphere of agricultural research is private industry; here, however, I am concerned only with the division of publicly-supported research between agricultural and nonagricultural institutions, not with proprietary research.)

Eventually, however, the intellectual isolation of agricultural studies began to break down. Increasingly, institutions specializing in agriculture recognized the need to broaden their scope, if only to survive the sharp decline in the farm population.

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Thus the "agricultural colleges" or "A&Ms" of an earlier era became today's land-grant universities, having added nonagricultural departments and schools that to varying degrees are involved in agriculturally related research. (For simplicity, therefore, I confine this paper to non-land grant institutions, where the isolation from agriculture is strongest. However, the arguments also apply to land-grant universities whose nonagricultural departments have chosen to remain aloof from agriculture.)

Bridgebuilding from the other direction has been longer in coming, but some changes are worth noting. In the 1970s, for example, the National Science Foundation—an agency not traditionally involved in supporting agricultural research—significantly funded research on the environmental and resource implications of agricultural production, with many grants going to non-land grant institutions. The competitive grants program established under the Food and Agriculture Act of 1977 (Title XIV, Subtitle C, Section 1414) was specifically intended to open the field to all kinds of institutions, in contrast to older Hatch Act funds earmarked for the agricultural colleges and their associated experiment stations. Also, grants in specific areas such as water quality are available to researchers outside the land-grant system.

Despite these significant changes, however, little public agricultural research is done outside the mainstream, "official" agricultural research system consisting of the agricultural colleges, state experiment stations, and the U.S. Department of Agriculture. (There are exceptions, however, such as research on agricultural biotechnology and on the fate of pesticides and other environmental pollutants. Also, research on the rest of the agricultural sector, such as food processing and marketing, is much more widely distributed than the production research with which I am concerned.)

We can see the dominance of the mainstream system from who received competitive grants under the new National Research Initiative, a much larger version of the 1977 program. These grants are intended to complement current formula-funded experiment station research by supporting basic research relevant to agriculture. Not only are they available to nonagricultural institutions, but they cover the kind of agriculturally related research that should be especially attractive to such institutions because it is not directly concerned with specific production techniques (an issue I discuss later in more detail). Because the various sections of the program differ in how much they have to do with agriculture, I looked at those with the greatest concentration of what might be called "basic *agricultural*" as opposed to "basic" research projects (again, a distinction I take up later). These include: Plant Pathology/Weed Science; Entomology/Nematology; Plant Genome; Plant Responses to the Environment; Ecosystems Research; and Rangeland Research (USDA-CSRS, 1992). All but 15% of the 1992 research grants in these categories went to a state experiment station, USDA, or a land-grant university (specifically, the campus with the college of agriculture, although not necessarily the college of agriculture itself). Moreover, even these more agriculturally oriented sections of the program include many individual grants that have little direct connection with agriculture (for example, they involve nonagricultural species). Consequently, the figure of 15% includes many projects where we would expect nonagricultural institutions to be well represented despite the prevalent separation between agricultural and nonagricultural research.

The Noncompeting Roles of Agricultural Colleges and Other Institutions

Today, many demands are being placed on agriculture beside the traditional one of producing an abundant and varied food supply reliably and efficiently. Agriculture is now expected to continue meeting this goal while fostering the economic and social well-being of rural communities, becoming more sparing in its use of resources, protecting environmental quality, and ensuring the wholesomeness and safety of our diet. To achieve these manifold goals, agriculture will need all the help that research can give it; for research to be adequate for the task, it will need all the talent and scientific insight available to it. Much of that talent and insight—potentially, at least—lies outside the traditional agricultural research system.

To date, the major contributions from that quarter have been *about* agricultural research, rather than agricultural research as such. That is, they largely have dealt with matters such as the politics of agricultural research, its goals and ideologies, its social and economic consequences, and so forth. This is not surprising, for two reasons. First, nonagricultural institutions usually lack the facilities needed to do agricultural research in the usual sense. Second, "outsiders" who are not so directly involved in research are more likely to look at it from somewhat greater distance and say "Here are things you should (or shouldn't) be doing, here are the important areas you have overlooked, etc." However, I am arguing that they should play a greater role in agricultural research as such, including "hard" scientific investigations, not just "softer" social, political, or philosophical analyses.

To be realistic, however, we must acknowledge that any proposal to open agricultural research to nontraditional institutions will run into objections from those who wish to preserve their current near-monopoly. Historically, the land-grant system has not been responsive to letting "outsiders" encroach on what traditionally was almost its private domain. We can see this, for example, in the strong opposition raised to funding the 1977 competitive grants through an offsetting cut in Hatch Act formula funds (Stansbury, 1986). Defending one's territory is an understandable instinct, even more so today, when adequate funding is so hard to come by.

It should reassure potential objectors, therefore, to hear what a staunch early supporter of the land-grant system, Liberty Hyde Bailey, had to say about the role of non-land-grant institutions (this at a time when the land-grant system was on a much shakier foundation):

> The teaching of agriculture of college and university grade ought not to be confined to colleges of agriculture. All universities, . . . for their own best development, will in time have departments of agri-

> culture, if they are real universities, as much as they have departments of language or of engineering. They cannot neglect any fundamental branches of learning. (Bailey, 1909, p. 225)

No doubt it takes a special breadth of vision, such as might be found in a Liberty Hyde Bailey, to welcome another institution's activities as complementing one's own, rather than competing with them. I will assume that enough people in the land-grant system will share Bailey's thoughts on the matter:

> When the state has divided its work of higher education between a university and a college of agriculture . . . hostility between the two lessens the efficiency of each. It is particularly important that neither one of the institutions should become possessed of the idea that its work is in the nature of the case more important than that of the other. . . . The province of educational institutions is to fight ignorance, not to fight each other. (Bailey, 1909, pp. 223-224)

Diversity of Institutions for the Diversity of Research Needs

The basis for believing that two different classes of institutions can play complementary rather than competitive roles lies in the twofold nature of agricultural research, which in part takes its character from agriculture, in part from research. Agriculture in some ways is like other production processes, and in some ways is like other natural processes, but it has a character all its own because of the unique way it blends natural, technological, and human elements. Agricultural research, similarly, derives some unique characteristics from the special nature of agriculture. Yet it also shares generic characteristics with many other branches of research: it uses similar methods, seeks similar kinds of knowledge, and trains its practitioners in similar ways. Depending on the particular research area, either the uniquely agricultural or the more generic elements will be more prominent (Lockeretz and Anderson, 1993, Chap. 4).

Correspondingly, different kinds of institutions—some specifically agricultural, some more broadly based—may be best equipped to handle these respective kinds of research. In principle, a single kind of institution might cover everything. I believe, however, that the coverage would be better if different kinds of institutions dealt with research areas of different scientific character. Besides benefitting the field as a whole, such an arrangement might even benefit the agricultural colleges in particular, by relieving them of the tensions that arise when a single institution is pulled in several conflicting directions at once. It also could help enhance the credibility of agricultural research as a whole by offsetting the perception—whether or not it is justified—that the field is too beholden to industry, such as agricultural chemical manufacturers. Presumably, because research at nonagricultural institutions would not be concerned with specific applications, it would be less susceptible to the undue influence of private economic interests, such as through product-oriented research grants that can shift a department away from work of broader social value (Strange, 1988, pp. 216-220).

The characteristically agricultural aspects of agricultural research dominate studies of agriculture as a production process. Agricultural production takes place in the "real world" outside the university and the laboratory. Research with this orientation, the kind that fits the everyday notion of "agricultural research," is well established at existing agricultural institutions, where it clearly belongs. (However, I do not mean to restrict "studies of agriculture as a production process" to its traditional connotation of "production-increasing" research. Research on the nutritional value of foods produced in different ways, for example, or on how different production methods affect groundwater quality, also are studies of "agriculture as a production process." Although the agricultural colleges historically may have given too little attention to such research, they are a suitable location for it provided they have the motivation.) The agricultural colleges have the best knowledge of their states' agriculture, the most experience in this kind of research, the strongest links to farmers, and the most appropriate facilities and supporting services. Moreover, they have a well-established tradition of service to farmers (and others), which implies a commitment to practical, problem-oriented work with clear and immediate applicability.

At the other extreme is research that eventually can be significant for the practice of agriculture, but where the connection is so indirect that the term "agricultural research" does not seem appropriate. Because photosynthesis, say, is so important in agriculture, any study that advances our understanding of it may help agriculture eventually. However, if there is nothing agricultural about the research itself (as is true, for example, with many projects funded by the National Research Initiative), the term "basic research" seems more accurate. Such research is, of course, well established at many institutions, both agricultural and nonagricultural.

Between these poles lies a kind of work that is generically scientific in its methods and in the types of questions it addresses, but where the agricultural connection is critical. Like basic research, it deals with the fundamental processes that underlie all agricultural production, such as photosynthesis, plants' response to stress, plant-insect interactions, and so forth. It also may deal with fundamental human elements of agriculture, such as perceptions, decision making, values, and ethical issues. Whichever its orientation, it concentrates on the aspects of these subjects that are specific to agriculture. For example, it will study photosynthesis in an agriculturally significant species, not just any plant. In short, it is *agricultural* research, although it has a more "basic" flavor.

Such research is sometimes assumed automatically to be "reductionist," a concept that is anathema in sustainable agriculture circles these days. However, it might deal with an entire ecosystem, for example. The distinction between this research and the more purely agricultural kind described earlier does not lie in the narrowness or breadth of what it studies, but only whether it is specifically about agricultural *production*; the kind described here deals with processes that are agriculturally significant, but that for study purposes have been abstracted from the context of any particular agricultural production system.

To do such research, it is not enough to be a good plant physiologist. One also must know enough about agriculture to choose the specific research question appropriately from among the many questions that plant physiologists might study. Also, although such work is not about any particular production system, one must also know enough about agriculture to be able to work out its implications for those people who are mainly concerned with production systems. Thus, it requires a hybrid scientist: one who is solidly in an established discipline relevant to agriculture—a very broad range!—but who also clearly identifies with *agriculture*, not just with science, and is willing and able to exchange ideas with specialists in the more practice-oriented agricultural disciplines. Such scientists already exist at agricultural institutions, but they also could thrive in receptive science departments of nonagricultural institutions. Similarly, scholars in humanistic and social science departments of nonagricultural universities, for example in departments of anthropology, history, education, and communication, potentially can make a great contribution to our fundamental understanding of the human side of agriculture.

I hope that eventually there will be more scholars of this kind. Ideally, they would have a continuing involvement in agriculturally related research, beyond just doing specific projects when suitable external funding became available (the National Research Initiative, for example). The entire department, not just the occasional individual who happens to be inclined that way, should have at least a modest continuing commitment to the agricultural aspect of its field, just as it already will have a continuing commitment to many other subspecialties (but not, generally, the agricultural one).

These institutions' lack of specifically agricultural research facilities is not a great drawback in such research. More important is that they would make available to agricultural research an increased breadth of *scientific* understanding and experience, complementing the specifically *agricultural* kind. This scientific foundation encompasses many fields that are, or should be, more closely linked to agriculture: microbiology, for example, not just soil microbiology; entomology, not just economic entomology; economics, not just agricultural economics. The great contribution of researchers in these fields could be to combine the orientation and goals of the agricultural disciplines with the cumulative scientific strengths of the larger disciplines, but without ignoring or subordinating the former. Although the term "interdisciplinary" has become a buzzword in many agricultural research circles, the type of interdisciplinarity that is advocated usually involves only the agricultural disciplines; little is said about spanning the gap between the agricultural disciplines and related scholarly fields.

We often hear, for example, about the complexity of sustainable agricultural systems, and of the alleged inability of current scientific thought to handle such complexity. Consequently, it is a commonplace in sustainable agriculture research circles that fundamentally new interdisciplinary approaches are needed for understanding sustainable systems. However, remarkable progress has been made outside agricultural science in understanding a wide range of very complex systems, whether biological, physical, or social. Rather than giving up in frustration, or setting out on a very ambitious program to create an entirely new agricultural science, wouldn't it be better first to take full advantage of relevant achievements in the sciences that have something to contribute to agriculture?

Can a Newcomer Contribute to Agricultural Research?

The kind of researcher I have described already exists in some departments of the agricultural colleges, but by involving the corresponding kinds of researchers from nonagricultural institutions, agricultural research could draw from a much larger talent pool. These newcomers to agricultural research would, of course, have to educate themselves about agriculture. However, scientists must always be learning so many new things anyway, just to keep abreast of developments in their own fields. By comparison, the difficulties of acquiring a sufficient knowledge of agriculture do not seem very formidable. This is especially so for the kinds of research I am discussing, in contrast to the more intensive familiarity with agriculture needed for production-oriented research.

The main barrier seems to me to lie not in nonagricultural researchers' ability to contribute to agriculture, but their interest in doing so. To overcome this barrier will take some work in both camps, especially to establish better communication between them. On one hand, researchers at agricultural institutions must present their field in a way that appeals to and challenges the best minds among outsiders. For example, when appropriate they could publish some of their work in more general research journals, rather than just in journals specifically concerned with agriculture. So, too, they might participate more in the activities of broader professional societies, either as individuals, or, if enough of their colleagues are similarly inclined, through formal collaborations between societies. They also must be openminded enough to accept or reject research according to its scientific merit, not whether it has the "look and feel" that agricultural researchers are familiar with. Researchers from outside the agricultural research establishment can be expected to view a given phenomenon differently from their more agriculturally trained counterparts, and to use different language and concepts in reporting their work; these differences are precisely why I believe that nonagricultural disciplines can make an important contribution.

Nonagricultural institutions, correspondingly, must overcome an unfortunate but long-held prejudice against agricultural research as less than first-class science (Danbom, 1992). Also, they must commit themselves to the goal of *serving* agriculture, not just analyzing it, even if their "service" is less immediate and direct than that of the agricultural institutions. Unfortunately, this may conflict with the "pure research" ethos of the traditional research university.

What Kinds of Research Will Advance Agricultural Sustainability?

So far, I have not talked about sustainable agriculture. The previous discussion applies to a wide spectrum of research. Is it particularly applicable to sustainable agriculture research? Is it applicable at all?

The question is real. The reasoning behind my recommendation seems to go directly against the main currents of sustainable agricultural thought. Advocates of sustainable agriculture generally call for research that is *more* directly tied to farmers' needs, *more* immediately applicable to actual practices, and *more* often conducted on farmers' fields. This is precisely the kind of research that nonagricultural institutions are least equipped to undertake. How, then, can recommending a bigger role for such institutions be reconciled with working toward a more sustainable agricultural system?

The answer is that the types of research being called for by sustainable agriculture advocates span only part of the range of needed research (Lockeretz and Anderson, 1993, Chap. 2). That is why the title of this paper refers to "researchers contributing to agricultural sustainability," as opposed to "sustainable agriculture research." The reason I make the distinction is that the term "sustainable agriculture research" has largely become restricted to a particular style of research, not just research with a particular goal—it is a label for how, where, and by whom the research is done, not just why.

The restriction is unfortunate. "Sustainable," by definition, implies thinking about long-term consequences; sustainability can hardly be evaluated just through short-term studies aimed at solving immediate production problems, the kind most favored by many sustainable agriculture groups.

Also, sustainable agriculture is supposed to be more "information intensive." The idea is that sophisticated understanding and use of information is an attractive way to reduce the dependence on agricultural chemicals and other manufactured inputs characteristic of conventional agriculture (Lockeretz, 1991). Where, though, is this understanding to come from? To be sure, we may already know how to farm better than we are farming, and we should make the best use of all the knowledge, understanding, and experience accumulated by farmers, researchers, and anyone else. Once we have done so, though, the job is not over. We still will need much better insights into agricultural systems, a plausible source of which are the agriculturally related fields that have not yet been fully exploited by agriculture.

Finally, sustainable systems are supposed to be *alternative* systems, something different—perhaps very different—from what we already have. If so, how can we investigate them if most of the work is supposed to respond to problems farmers are having with their current systems, and if it is to be done largely on farmers' fields? There are many advantages to doing research on farmers' fields, but investigating radically different alternatives is not one of them. An important benefit of on-farm research is that it makes the research setting more realistic. But this benefit is obtained only for systems that fit into the current structure of the farm; there is no way to do a realistic on-farm study of a system requiring a kind of farm not already found in the area, such as a diversified crop-livestock farm in a region dominated by specialized cash grain production. Yet the *structure* of an area's farms—size, enterprise diversity, relative importance of capital and labor, and so forth—may be much more important for their sustainability than the details of the production methods they use. Also, farmers are not likely to allow their farms to be used for risky or speculative research on unconventional alternatives that we do not yet know much about, or for alternatives that significantly conflict with their management routines. Ironically, then, emphasizing on-farm research restricts sustainable agriculture research to the conventional end of the spectrum of alternatives.

Accountability in Sustainable Agriculture Research

Thus, a research program intended to make agriculture more sustainable should consist only in part of the farmer-oriented research that many sustainable agriculture groups have been advocating. It also should include speculative and long-range research, and research that is concerned with fundamental concepts of agricultural production systems rather than just with specific production systems (and especially not just with those systems that some farmers already are using). To achieve this will require that we allow some researchers to be less directly accountable to outside groups, whether farmers or anyone else, and less obligated to show the immediate practical value of their work.

Granted, this could be interpreted as giving such researchers a great deal of license; often, those who wish to work in this mode are condemned as careerists who place professional prestige over service. However, the alternative to "immediately useful" is not necessarily "useless." Again, it should help reassure us to hear how Bailey—a strong believer in the land-grant system's service mission ("a college of agriculture . . . should be allowed to devote all its efforts to serving the people" [1909, p. 223])—felt on this point:

> There may be need, also, of a kind of agricultural work that can best be done in an institution . . . that is not at once responsible to popular will. (p. 225)

In principle, a college of agriculture could fulfill the diverse research needs of sustainable agriculture. But when an institution is pulled in different directions—directions that apparently are contradictory, although they all can contribute to the same long-range goal of sustainability—a likely outcome will be "all or nothing."

Interestingly, the debate over farmer-oriented versus scientifically motivated research was an important controversy in the early days of the experiment station system (Danbom, 1986). Noteworthy in this regard are the views of one its most illustrious leaders, Whitman Jordan. Jordan clearly qualifies as totally committed to the notion that public agricultural research exists to serve real needs: "Those of us who are devotees of applied science . . . declare with great fervor that we will have nothing to do with knowledge that cannot be brought into the service of humanity. We are glad that learning has escaped from the monastery into a throbbing, busy world. We have no sympathy . . . with those who claim to be working in the field of what is designated as pure science and affect contempt for the utilitarian" (Jordan, 1908, p. 134). Given this perspective, it is interesting to hear his views on how responsive

researchers should be to pressures to be directly and immediately useful:

> The agricultural public is not always patient or discriminating.... Because a constituency that has no adequate conception of what research involves complains to its representatives in the legislature that the appropriations for agricultural investigation are not producing equivalent values, the investigator is placed in a position of defending himself before a jury that does not understand him. The condition of expectancy that prevails on the part of the public that it must have results of immediate value to practice, and on the part of various institutions that they must have public support, has been an element most dangerous to the quality and integrity of our work.... It will be fortunate when our research efforts shall be farther removed from the disturbing influences of an indiscriminating public sentiment. (Jordan, 1908, pp. 142-143)

This view would not, however, sit well in some circles today, as seen in the following statements from two farmers who are especially involved in sustainable agriculture research:

> Our educational system . . . instills a sense of intellectual superiority among scientists and the assumption that only they can and should determine research needs and design. This elitism must be overcome. (Watkins, 1990, p. 161)

> Researchers don't want anyone telling them what they ought to be doing. Any demands for research accountability and responsiveness to farmers' needs are perceived as threats to the creativity of researchers.... No one wants to stifle scientific genius; we certainly need innovativeness in agricultural research. But we also need to have scientists focus their work on priority issues identified through a democratic process. (Thornley, 1990, p. 175)

Nonagricultural institutions, precisely because they do not have a tradition or obligation (whether moral or legal) to serve practical needs, are suitable places to pursue one important portion of the agricultural research spectrum. Fortunately, too, this is this kind of agricultural research where general scientific strength, the great asset of nonagricultural colleges, is more important, and where the lack of experience with agriculture is less of a problem.

Developing a truly sustainable agriculture will require bold, imaginative, thinking *and* a strong firsthand familiarity with practical agriculture. It will require that we merge the science, the craft, and the art of agriculture. It also will require that researchers listen to farmers telling them what problems are most important, but *not* that they always choose their research questions accordingly—not because one group's views are more or less legitimate and valid than the other's, but because the full spectrum of legitimate and valid research questions is much broader than what any one "outside" group, whether farmers or anyone else, is likely to suggest. (Everyone would be better served, however, if researchers explained to farmers why they were pursuing research topics besides those suggested by farmers.)

Given the diversity of research needs, it seems imprudent—and against the spirit of sustainable agriculture, where diversity is a key strategy—to entrust the entire task to a single institutional system. Researchers at nonagricultural institutions clearly have the ability and, to an encouraging but still small degree, the willingness to make an important contribution. Those in the land-grant system who are sincerely pursuing the goal of agricultural sustainability will not feel threatened by this willingness, but will welcome and foster it.

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Farmer initiated on-farm research

Ronald L. Rosmann

Abstract. *Practical Farmers of Iowa was founded in 1985 to help farmers generate and share information on environmentally sound farming methods. Its on-farm research trials allow farmers to do statistically valid comparisons of competing techniques, such as different weed control methods. However, sustainable agriculture means more than providing farmers with adequate information about appropriate techniques. It also requires policies that reward farmers for adopting sustainable methods and that support rural community well-being.*

Key words: farmer-initiated research, sustainable agriculture, environmentally sound farming, extension, rural communities, farm families, ridge tillage

Introduction

Farmer participation in the land-grant university (LGU) system and agricultural research has had a long up-and-down history, with both conflict and success since the system began in 1862. Farmer input into university decisions and communication between farmer-citizens and the university were among the goals of the LGU system (Stevenson and Klemme, 1992). However, most farmers did not want agricultural colleges or experiment stations (Danbom, 1992). Many began to blame the LGU system for rural socioeconomic woes arising from low prices and profiteering by the marketing and transportation sectors, specifically the grain merchants and railroads. Some early experiment stations encouraged farmers to do experiments on their own farms and share the results with scientists. Although agricultural researchers candidly admitted the experiments were scientifically dubious, at least they had public relations value (Danbom, 1992). Responsiveness to farmers' concerns gradually declined after World War I. The next 60 years were the Golden Age of agricultural research, with great strides in productivity resulting from the development of hybrid corn, pesticides, and chemical fertilizers. Farmers became highly dependent on the experiment stations and the universities for information. By the 1970s, however, some people began to see that they were paying for this rapid increase in productivity and technology, as negative effects were being felt around the countryside. The rural social stability of the 1940s, 1950s and 1960s started to become unglued. Farms were getting larger, farmers could work more land, and machinery was getting bigger and more costly, which helped fuel the need to farm more land. Rural communities were experiencing economic decline and loss of population, and their groundwater was becoming contaminated from the overuse and misuse of pesticides and fertilizers. The high costs of energy and other inputs in the 1970s caused some people to look elsewhere for alternative solutions. For some, the solutions were to be found, astonishingly, within themselves.

Thus, the groundwork was laid for an organization such as the Practical Farmers of Iowa (PFI) to build on the crumbling foundations of farmer involvement in university affairs during the previous 120 years. Auburn and Baker (1992) commented that farmers can inform agricultural research in three ways: as objects, as advisors, and as full partners in control of research. PFI chose the last of these as their primary strategy, although perhaps it should be amended to read "full partners for the good of all."

History of PFI

PFI was founded in 1985 to generate data and share information on profitable, environmentally sound farming methods. In 1984, Larry Kallem, executive director of the Iowa Institute of Cooperation, and Richard Thompson, a farmer from Boone County, Iowa, began discussing the need for a group that could pursue that purpose. At a 1985 Iowa State University (ISU) workshop entitled "Management Alternatives for Biological Farming," farmers were asked about forming an organization of farmers interested in this approach. The response was an overwhelming yes, and a small group was formed, calling itself Practical Farmers of Iowa. The word "practical" was selected because the organization had to be realistic so that farmers would be interested in joining. Also, to make it appeal to as many farmers as possible, words such as "organic," "biological," and "regenerative" were avoided.

PFI has grown steadily since 1985, with its membership now around 450. It is best known for its involvement in sustainable agriculture and on-farm research. The first goal in its original mission statement was to provide farmers with information about environmentally sound, lower cost, profitable farming techniques. By the early 1980s, many farmers were becoming concerned about trends they were seeing, including: increased dependence on pesticides, with its possible associated environmental and health consequences; increased loss of topsoil with conventional tillage; loss of medium-sized family farms; increased dependence on fossil fuel; higher costs of purchased agricultural inputs; deterioration of rural communities; and loss

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of control over their personal and business lives.

PFI's second goal was to encourage and guide research aimed at producing information about sustainable agriculture. This has been a major way of bridging the gap between farmers and scientists. It never would have been achieved if the ISU Extension Service had not been willing to listen. Because of this openness to real farmer involvement in research, a PFI/Extension field coordinator was named in 1988. The coordinator is an Extension agronomist who has worked on behalf of both the Extension Service and PFI in a partnership that reflects both groups' commitment to sustainable agriculture and the communication process.

History of the Field Experiment Design

The need for practical, scientifically sound on-farm trials evolved from the work of Richard Thompson. In the early 1980s, many researchers doubted the credibility of on-farm research. Busch and Lacey (1983) asked agricultural scientists to rank different criteria for choosing research problems. Although "demands raised by clientele" was listed 13th of 21, there was no mention of farmers' observations or on-farm research as contributing to selecting a research problem.

This omission was justified. "Research" done on-farm was largely based on farmers' observations from one field to the next, one year to the next, or, at best, one field subdivided into a few wide strips comparing two practices. On the other hand, farmers were reluctant to accept data from small plots on university field stations that were planted and harvested by hand. The yields usually were high and not realistic according to farmers' experience.

Thus there were two extremes, one based on farmers' unreplicated field observations, the other based on small, unrealistic plots off the farm. A compromise was needed. Out of these concerns evolved the design for farmer-managed paired comparisons used by PFI farmer-researchers (Exner and Thompson, 1992), which has become the cornerstone for valid, reliable farmer initiated investigations.

Description of the Experimental Design

The field trial design has evolved to include the following characteristics:

- There are at least six randomized replicates, with long, narrow strips that run the length of the field.
- Generally, only two treatments are compared.
- The farmer's conventional equipment and field operations are used.
- Selection of the research topic is primarily left to the farmer.
- Plot work is performed entirely by the farmer.
- Appropriate soil tests and leaf tissue analysis are done.
- Yields, weed counts and other appropriate measurements are made by the farmer.
- Trials are subjected to statistical analysis, often by the farmer.

From 1987 to 1992, 298 trials were conducted by 27 farmer-cooperators (Table 1). Table 2 shows the kinds of trials. Besides the replicated trials, there were 79 unreplicated demonstrations.

Evaluation

PFI field trials have both strengths and weaknesses compared with field station research. The advantages of field station research are:

- It can do long-term studies more readily because of fewer cropping restrictions from year to year.
- It does not have the economic constraints facing most farmers.
- It can investigate the dynamics of why a practice works or doesn't. PFI trials can show what happens, but not necessarily why.

Advantages of on-farm research include the following:

- Farmers find its results more believable.
- It tests new techniques under the realistic conditions of actual working farms.
- It is conducted as part of a whole-farm system under actual farming conditions.
- It provides farmers with new skills and enhances their confidence in their problem-solving ability.
- It can lead to more rigorous research by scientists.
- It is economical, because farmer-researchers are reimbursed up to $350 per trial, with one or two trials conducted per year.
- It provides statistically reliable answers.

Table 1. Replicated on-farm trials, Practical Farmers of Iowa.

Year	Number of Trials
1987	9
1988	41
1989	59
1990	61
1991	68
1992	60
TOTAL	298

Table 2. On-farm trials, Practical Farmers of Iowa, 1987-1992.

Category	Number
Cover crops	16
Manure management	19
Miscellaneous	33
N rates	76
P & K rates, placement, and timing	21
Starter fertilizers	33
Tillage	20
Weed management	68
Narrow strip intercropping	6
Management-intensive grazing	6
TOTAL TRIALS	298
Demonstrations	79

Statistical Reliability

One measure of the statistical precision is the coefficient of variation (C.V.). Rzewnicki et al. (1988) compared experiment station C.V.'s in south central Nebraska to those from 23 PFI trials in 1987. Irrigated corn yields in experiment station trials had C.V.'s in the range 8% to 15%, with least significant differences (LSD) from 15 to 23 bu/A. For irrigated soybean trials at the same experiment stations, C.V.'s were from 6% to 12%, with LSD's from 3 to 6 bu/A. By comparison, 23 PFI trials had an average C.V. of 2.7% (range 0.7% to 5.9%). The authors concluded that the statistical reliability of the on-farm design should enhance the development of integrated research models that included farmers, Extension personnel, and researchers.

Further improvements are being made in the PFI field trial design. One is to include more checks in the standard two-treatment design. Another is to replicate the same treatment at multiple locations and over multiple years instead of different treatments tested for only one or two years.

Relevance to Sustainable Agriculture

From the viewpoint of promoting sustainable practices, how successful have the field trials been? From the onset, they were intended to show that farmers could farm both profitably and in an environmentally sound fashion using fewer purchased inputs, especially pesticides and fertilizers. Two of the most popular trials have been comparisons of nitrogen (N) rates and of weed management methods. Table 3 shows the results of 71 trials from 1987 to 1992 in which the farmer's customary N rate was compared with a reduced rate based on the late spring soil nitrate test adapted for Iowa by Alfred Blackmer, ISU agronomist. There were no significant yield differences, with the lower rate saving an average of 53 lb of N, $6.68, and 12.7 gal of diesel fuel equivalent per acre.

Table 4 summarizes 20 corn trials and 29 soybean trials for weed control using ridge tillage with mechanical cultivation only or with mechanical cultivation plus herbicides, which usually were applied in a narrow band over the row. There were no significant yield differences between the two. The average saving from not using herbicides was $5.50/A for corn and $5.78/A for soybean.

The PFI on-farm public field days have been the most effective means of disseminating results such as these (Table 5). Nearly 8,000 people have attended the 137 field days since 1987, many of which were cosponsored by the local Extension office, Soil Conservation Service, or agribusiness groups.

Implications for the Future of Agriculture

Critics such as Jim Hightower (1973), in his book *Hard Tomatoes, Hard Times*, have charged that LGU research is biased toward larger farms. Defenders of LGU research have argued that their technologies are scale-neutral, and that larger farms simply can adapt them more readily. According to Smith (1992), however, neither side is correct: "Land grant university research is not directly scale biased, it is sector biased." He has said that most agricultural research leads to more non-farm economic activity at the expense of farming. He gives the example of the bovine somatotropin (bST), in contrast to management-intensive rotational grazing. Adoption of bST will substantially reduce farming activity but increase non-farm activity, whereas a shift to rotational grazing could result in more farming without increasing the cost of producing milk.

PFI, with its emphasis on an integrated systems approach to farming, has significantly contributed to increasing farming activity. PFI research farms ideally are diversified in crops and livestock, with significantly lower purchases of off-farm inputs but significantly higher recycling of nutrients, and with labor and management provided largely by the farm family.

PFI has shown that farmers can become full partners in research for the good of all. Although farmer-driven on-farm research has been an asset, PFI recognizes that more efforts are needed if further change is to take place. Unfortunately, PFI and sustainable agriculture still are viewed by many as outside mainstream agriculture. Originally, PFI wanted to change mainstream agriculture. It now asks whether that is realistic, since food production, processing and marketing are becoming more vertically integrated and under the control of very few companies. Many people have not heard of PFI, although it has had considerable impact at the state and national level. This shortcoming will be addressed through a long-term project called

Table 3. Results of 71 N rate comparisons, Practical Farmers of Iowa, 1987-92.

Practice	N (lb/A)	Corn Yield (bu/A)
Farmer's customary rate (av.)	133	132.8
Alternative rate (av.)	80	131.3

Table 4. Weed management trials, Practical Farmers of Iowa (1987-1992).

	Corn	Soybean
Average yield (bu/A)		
Ridge tillage with herbicide	132.1	43.0
Ridge tillage without herbicide	132.6	42.2
Number of trials (six replicates per trial)	20	29
Saving from omitting herbicide ($/A)	5.60	5.78

Table 5. Farm field days, Practical Farmers of Iowa.

Year	Number	Attendance
1987	9	800
1988	18	1000
1989	22	1000
1990	29	1400
1991	30	1800
1992	29	1900
TOTAL	137	7900

"Shared Visions: Farming for Better Communities," which will create local focus groups in farming communities around Iowa to broaden the scope of PFI activities. A diverse mix of citizens will make up the local groups to work on forming a "shared vision" and a plan to implement these goals locally. The local on-farm research network will be linked to the new community groups serving as a focal point for educating both farmers and nonfarmers about the value of sustainable agriculture. Local marketing is an example of an issue where local groups can become involved.

PFI is very concerned about the farmer's declining share of the agricultural dollar, more of which now goes to the marketing and input sectors. Members often have said that even if they did all the right kinds of research, farmed in the most environmentally sound manner possible, reduced purchased inputs drastically, and obtained high yields, they still might not survive because of factors that seemingly are out of their control, namely the prices they receive, federal farm policy, and macroeconomic trends. On-farm research data, such as PFI farmers have generated since 1987, could be used more effectively to influence federal farm policy and to reform farm legislation so that farmers are rewarded financially or encouraged in other ways to use the kinds of sustainable agricultural practices that PFI has examined. PFI data provide real-life evidence that large-scale farming with reduced purchases of pesticides and fertilizers does not mean large decreases in yields and income (Blackmer, 1993).

PFI recognizes that sustainable agriculture is more than on-farm research or a set of farming practices. It also is about values and people. Small and medium-sized family farms, vibrant rural communities, the entry of young people into farming, and an increase in the producer's share of the agricultural dollar all are worthy goals. Our challenge is now to make them a reality.

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Farm Profiles Invited

For its new department on alternative agriculture profiles, the *AJAA* welcomes short articles describing farmers who have adopted interesting alternative practices. The articles should include five elements: a brief description of the farm; the problems that made the farmer look for an alternative approach and the reasons why the alternative seemed plausible; a summary of the basic principles behind the alternative (possibly in a sidebar if it interrupts the flow of text); a discussion of how well the alternative has worked; and a discussion of the applicability of the alternative for other farms. The length should be 1500 to 2000 words.

Submissions must be accompanied by a release, signed by the farmer, giving permission for this material to be published in the *American Journal of Alternative Agriculture*. Vol. 3, No. 4, of the *AJAA* has a further description of the department (page 188); or query the editor for further information. Send submissions to the Editor, *AJAA*, 9200 Edmonston Road, Suite 117, Greenbelt, MD 20770-1551.

Compost is Being Turned into "Natural" Pesticides by Recycler

Land Recovery Inc. in Washington is taking compost beyond its typical fertilizer function by turning it into natural pesticides and fungicides, according to a recent article in *The New York Times*. "The idea is to treat the compost, produced here from yard wastes, with microorganisms specifically designed to attack the fungi and bacterial diseases that horticulturists now typically fight with chemicals," the article says. The commercially available microorganisms are natural enemies of fungi or microbes that cause bacterial plant diseases.

Whole farm case studies and focus groups: Participatory strategies for agricultural research and education programs

Helene Murray and Lorna Michael Butler

Abstract. *Research and extension personnel are beginning to look for new strategies to involve more farmers and the non-farm public in their programs. Two approaches we have used are whole farm case studies (WFCS) and focus groups. WFCS in Oregon and Washington led to several research and educational programming ideas that are currently being pursued in both states. A focus group to study water quality, nitrate leaching and farming practices in Skagit County, Washington is one outcome of the WFCS process. It is made up of 16 people, including farmers, university personnel, members of environmental groups, and government representatives.*

We review these two complementary participatory strategies for systems-oriented sustainable agriculture research and education programs. Both have been very useful for building problem-solving partnerships between the land-grant universities and agricultural and environmental constituents in our area. Noteworthy outcomes include: complementary applied on-farm and experiment station research; farming systems analysis; public education; new linkages with environmental and agricultural interest groups; additional grant funds to address identified priority issues; and interdisciplinary teams that cut across the biological and social sciences and include diverse citizen representation.

Key words: whole farm case study, focus groups, participatory research, systems research, qualitative research

Introduction

Under the 1985 farm legislation, the U.S. Department of Agriculture (USDA) was directed to pursue research and educational activities in low-input sustainable agriculture (LISA). Now known as Sustainable Agriculture Research and Education (SARE), the program was designed to help agricultural producers to provide an inexpensive, plentiful and safe food supply while addressing some of agriculture's social, environmental, and economic concerns. A major goal of the SARE program has been to examine entire farming *systems*, not just specific components such as weed or insect control. The justification for this approach is that problems do not manifest themselves in isolation, so that understanding the system helps put complex interactions into context. To help accomplish this goal, a major emphasis of the SARE program has been to increase farmer participation in the development and use of technology.

In the past, land-grant universities (LGUs) perceived their most important agricultural audience to be farmers and leaders of farm organizations. This is rapidly changing, since a wide range of public groups clearly are concerned about agriculture. Research and extension personnel are beginning to look for new strategies to involve more farmers and the non-farm public in their programs. Two complementary approaches we have used are whole farm case studies (WFCS) and focus groups. Both strategies can help give direction to on-farm research, experiment station research, and educational activities, and both can help build more effective partnerships between members of the public and the LGU. Rather than describing the many specific results of these two projects, our purpose in this paper is to describe our experience using these methods and to outline some strengths and difficulties of each approach.

Whole farm case studies and focus groups contribute most when they are part of a larger research and education program. Fig. 1 shows where WFCS and focus groups fit within a program in western Oregon and Washington that seeks to increase farmer participation in research and education programs.

Whole Farm Case Studies

A whole farm case study is a systematic examination over time of the biological, social, and economic factors of an entire farming system, such as production practices, economic status, business management, and relations between farmers and employees. It relies primarily on qualitative information unlikely to be derived from controlled experiments or from one-time surveys, and, therefore, is excellent as a complement to quantitative research and

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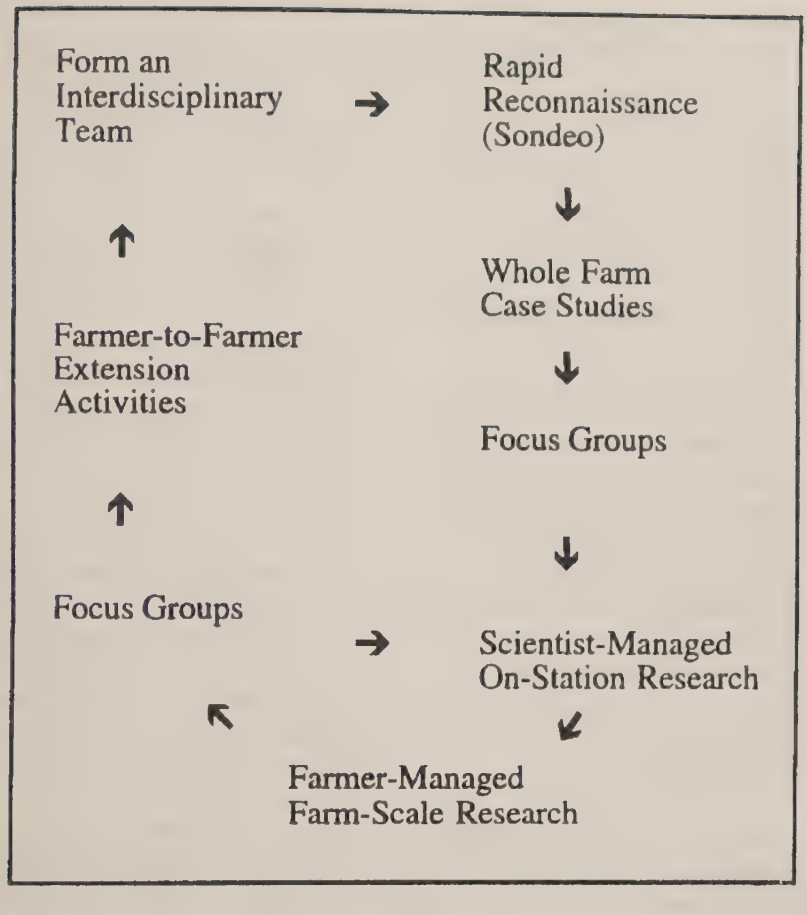

Figure 1. The western Oregon and Washington model for increasing farmer involvement in research and educational activities.

economic analysis. The case study approach has been used extensively in business, economics, and medicine. In agriculture, case studies can develop a better understanding of constraints, innovations, and human interactions in various production systems.

Because WFCS are designed to understand systems, participation of biological and social scientists and farmers in their development and implementation is crucial to their success. Among the factors to be considered when designing a WFCS are: its purposes, available time and money, expertise of team members, interdisciplinary goals and expectations, and the duration of the study.

During the design phase it is important to clarify the purpose and anticipated outcomes of the study. The design needs to be flexible enough to incorporate new information. It is important to have a plan, but it also is important to recognize that the plan will change. In our view, the process of building an interdisciplinary team is one product of the activity.

Using a collaborative team approach, Oregon and Washington State University personnel conducted WFCS of 16 small fruit and vegetable farms to provide direction for applied sustainable agriculture research and education strategies beginning in 1988. The 16 farms are located between Skagit County, Washington and Lane County, Oregon. Seven are certified organic farms, one has both certified organic and conventional production, and the remaining eight are conventional farms. In this paper we use the term "conventional" to describe those farms not meeting the requirements for organic certification. The farms range in size from 8 to 3,000 acres, with gross sales ranging from $10,000 to $4 million annually.

Rather than comparing farms within the study group, the goal was to identify different approaches to solving similar problems and to focus on farmer-developed innovations. The study included the following steps: development of an interdisciplinary team, design of the study, collection and analysis of data, and presentation of findings.

The Implementation Team for the OSU/WSU project consisted of research and extension personnel in both states in the following fields: agricultural economics, agronomy, anthropology, ecology, entomology, family economics, farming systems research and extension, home economics, horticulture, marketing, plant pathology, soil science, and weed science. A wide range of disciplinary expertise was sought to gain a broad understanding of the complex interactions of diversified farming operations west of the Cascade Mountains. A total of 34 OSU and WSU personnel worked on the project. Because the study was conducted in two states, we chose to form a team in each state with similar areas of expertise. A single team to conduct the study might have been preferable, but travel time and expense considerations ruled out this option. Allowing two teams to evolve encouraged more people to participate and to assume ownership of the process and its outcomes.

A sondeo was used to identify farmers willing to participate. A sondeo is a rapid appraisal survey commonly used in Farming Systems Research and Extension. It employs a flexible interview process, permitting in-depth examination of issues in a whole farm context (Hildebrand, 1981; Beebe, 1985). Using a few open-ended questions, farmers were asked about cropping patterns, marketing practices, pest management strategies, and problems associated with their operations. The sondeo gave the Implementation Team members an early opportunity to work together, get to know each other, and develop a common understanding of systems problems and potential solutions. It required the social scientists to focus on the complex production issues that confront producers, and required the biological scientists to consider equally complex social and economic issues. Farmers and team members together were able to identify research and education priorities. Brophy et al. (1991) provide a summary of methods and findings

from the sondeo interviews in Oregon and Washington.

After farms for the WFCS were identified, data were collected using several approaches: informal interviews; in-depth structured interviews; observation; forms completed by both farmers and Implementation Team members; soil and plant tissue testing results; photographs of production practices; and, when available, popular press articles and other printed materials about the farm, farm family, or specific production practices. Field notes were used to document interviews and observations. Use of multiple sources of information, known as triangulation of sources (Webb, 1966; Rossman and Wilson, 1985; Marshall and Rossman, 1989; Patton, 1990), contributed to the validity of the study.

At least three visits were made to each farm, besides the sondeo interview. The first visit focused on production practices, access to equipment, decision-making strategies, and sources of information. During the second trip to each farm, we talked with farmers about their production practices and decision-making strategies during the peak of the growing season. We also discussed marketing approaches and strategies during the first two visits. Data were recorded by individual team members as we toured the farm with the primary operator of the farm, or at least one member of the farm family. The first two visits lasted between two and four hours per farm. Before visiting each farm, team members listed information to examine and discuss during the visits. The flexible interview process enabled team members to explore topics and ideas in depth.

The final visit was more structured. Team members developed and used a questionnaire to gather specific information about management of each farm. Most questions asked during the third interview were open-ended, enabling respondents to elaborate on topics and allowing the interviewers to ask for clarification when necessary. We discussed household management, economic status of the farm, labor issues, and farm management during this visit. The interviews lasted an average of three hours each and were conducted by groups of two or three team members, including at least one biological and one social scientist. In this interview we also attempted to talk with each farmer's spouse or business partner to obtain their view of the farming operation.

We also requested data on farm labor use. We gave farmers a brief data form to record the monthly labor hours (both paid and unpaid) and electricity and fuel usage. All the case study farmers agreed to cooperate with this part of the study, but not all farmers supplied us with the requested information.

Data analysis was done by team members throughout the study. Implementation Team members met after each series of farm visits to discuss findings, observations and impressions, and to identify areas requiring clarification. Usually the meetings were in person, although a few were telephone conferences. Either these meetings were recorded and later transcribed, or detailed notes were taken to document the discussion.

Focus Groups

The process of conducting WFCS in western Oregon and Washington identified many research and educational needs, especially the need to include diverse stakeholders in the planning and implementation of projects. Some WFCS participants in Washington identified the focus group process as a way to involve non-university people in research and education projects.

Focus group discussions and interviews offer a way to understand and interpret how people see a particular situation or idea. The process involves collaborative learning through exchange of information and perspectives, which can generate information and insights that might not emerge from individual interviews. In a WSU project in Skagit County, 16 people representing diverse interests formed a group to study interactions among water quality, nitrate leaching, and farming practices. These topics were identified as priority issues during the WFCS study visits to Skagit Valley farms. Focus group members include row crop growers, representatives of agricultural industry, an extension agent, an extension specialist, a researcher, government agency representatives, a dairy producer, representatives of environmental groups, and a Tribal community member.

The WSU-Skagit County focus group has been giving direction to an applied research and education program focusing on nitrate leaching and water quality. Focus group members are learning from each other by sharing knowledge, experiences, opinions, and ideas, and are building a partnership of agricultural and environmental interest groups and research and extension personnel. The impetus was the growing evidence of excessive concentrations of nitrates in groundwater throughout several western Washington counties. With these findings came accusations that nitrogen from animal manures and commercial fertilizers was exceeding the needs of crops. Excess nitrogen, as nitrate, can leach into groundwater when rainfall or irrigation exceeds the waterholding capacity of the soil. The Skagit River, the largest waterway flowing into the Puget Sound, carries substantial quantities of nitrogen. This is significant for agriculture because the lower Skagit River drains about 68,000 acres of commercial farmland.

The topic was sensitive because Northwest horticultural producers and dairy operators pride themselves on being good stewards of the land. They do not believe their production contributes to nitrate contamination of groundwater. Most believe that if there is a problem, agriculture is not its sole cause. However, most farmers in the area are interested in learning about data on nitrate leaching generated under western Washington climatic and production conditions. With this objective in mind, focus group members met every four to six weeks to analyze the nitrate issue and its implications for western Washington farming systems. Since the first meetings in February 1992, members have met 11 times, in 2-hour time blocks. Table 1 shows the different topics and activities addressed since February 1992.

Dissemination and Linkages

Outcomes of both the WFCS and the WSU-Skagit County focus group have included new partnerships and teams committed to collaborative problem solving. For example, team members have cooperated on studies with the Padilla Bay Estuarine Research program and the Minto-Brown Island Park Agricultural Task

Table 1. Washington State University - Skagit County Cropping Strategies and Water Quality Project: Focus group phases and corresponding activities and topics addressed (February 1992-July 1993).

Phases	Activities/Topic Addressed (in sequence)
Phase I: Learning Together About Nitrates	• Soil nitrogen cycle • Human health and nitrates • Cropping strategies and water quality research and education project model • Introduction to station research • Skagit County watershed management and planning • Nitrates and forest ecosystems • Baseline survey of nitrates, water quality and farming
Phase II: Defining Research and Educational Needs	• Clarify and document focus group ideas, issues and questions • Focus group interview regarding nitrates and ground water contamination in Skagit County • Potential OFR
Phase III: Planning On-Farm Research (OFR)	• Implementation subteam preparation for focus group education regarding OFR • Education regarding designing and implementing OFR • Generate ideas for on-farm cover crop research • Identify cooperators – Project design – Cropping strategies field day
Phase IV: Implementing On-Farm Research	• Cooperators lay out cover crop trials on their own farms in keeping with their own system and resources • Developing an OFR evaluation tool • Evaluation of OFR (team, cooperators, laboratory)
Phase V: Understanding On-Station Research Results and Implications	• Expanding scientific knowledge regarding effects of winter cover crops, alternative fertilizers and rations, use of lysimeters
Phase VI: Planning for Public Education	• Alternative audiences – Environmental organizations, public • Important message • Alternative educational approaches • Focus group involvement in team presentations
Phase VII: Acquiring Additional Grant Resources	• Grower information needs for use of fall-planted cover crops • Need to develop *best management practices* (BMPs) for fall-planted cover crops • Focus group application for grant funds for development and documentation of BMP information • Grant funding secured (beginning 1/94)
Phase VIII: Broadening our Agenda to Include Wildlife Management	• Skagit Valley wildlife habitat and agricultural practices • Effects of increased use of cover crops • 'Poco' barley cover crop experiment launched • Survey of growers regarding history/extent of winter cover crops use

Force. Both projects have established linkages with national environmental groups and have addressed farming, wildlife, and agricultural-urban interface issues. In both Oregon and Washington, on-farm and experiment station research has been initiated on topics such as cover cropping, crop rotation, and alternatives to commercial fertilizer. Farmer participation is a key element of these projects. Farmers, researchers and extension agents jointly identify projects, plan work, and collect and analyze data. In the Washington focus group, members of the non-farm public also are part of the research team. Information is shared by field tours and workshops as part of the ongoing *Farming for Profit and Stewardship* conference series. In both Washington and Oregon the SARE projects have been augmented by private and government funding that has greatly increased the scope and amount of work.

Educational materials have been created for conferences and workshops to disseminate information about participatory methods and to convey research findings. WSU and OSU researchers and extension personnel have shared information at seminars and workshops with colleagues about the lessons that have been learned from participating in the focus group and WFCS. Publications about research results and methods have been prepared (Brophy et al., 1991; DePhelps, 1992; DePhelps and Butler, 1992; Butler, 1993; Lev et al., 1993; Murray et al., 1994a; Murray et al., 1994b).

Summary and Conclusions

The strengths and difficulties of the WFCS and focus group approaches are listed in Tables 2 and 3. Both approaches are time consuming; communication takes time, but ultimately is worthwhile. Interestingly, complaints about the time that must be devoted to these approaches come mostly from academics, not farmers. However, both projects have created new linkages among diverse groups, strengthening research and educational programs in both states. Land-grant university personnel have learned a great deal from farmers and other participants. Non-university participants also have told us that they value the knowledge gained in the programs.

Table 2. Strengths and difficulties of the Whole Farm Case Study (WFCS) approach

Strengths	Difficulties
• Allows great flexibility in addressing the specific needs, interests and goals of all participants	• Need to identify farmers willing to spend time and to share specific information about their farming operations
• Team members gain better understanding of the complexity of entire farming systems, not just components of agriculture within their areas of expertise	• The logistics of conducting this type of research can be challenging; need to have at least one team member who is willing to coordinate the day-to-day details of the study
• Identifies farmer-developed innovations	• The institutional rewards for conducting this type of research may be limited
• Provides an avenue for increasing farmer involvement in research and extension activities	• Analysis of qualitative information can be difficult and time consuming
• Offers a means of identifying research and education needs	• Requires team members to spend considerable time designing, planning and conducting the study
• Improves communication among a wide group of people	• WFCS research is expensive, primarily because of time involved in planning, data collection, discussion of findings, analysis and reporting

Despite the time commitment, team members participating in the Oregon/Washington WFCS project said that interaction with other team members provided them with new perspectives and enabled them to see how their disciplinary expertise complements analysis of whole farm systems. Working across state lines and institutions has been difficult at times, but it also has led to valuable new working relations and has laid the groundwork for future joint LGU efforts in our region.

The focus group approach is valuable as a mechanism to understand and interpret how different people see a particular situation or idea. Whole farm case studies, on the other hand, provide information about how systems function, and are a way to do interdisciplinary work and to increase farmers' involvement in research and education programs. Both approaches generate in-depth insights, suggest innovative solutions to problems, and build participants' ownership of outcomes.

Farmers who have participated in the case studies and focus groups have exchanged information with other farmers and have received nutrient analysis results and specific answers to questions from participating scientists. Farmers have been invited to participate as teachers and presenters at meetings and conferences and to serve on prestigious advisory boards and committees. The process also has facilitated exchange of information with other people in the United States and in several other countries. Valuable linkages have been made between environmental and other interest groups. Some of these linkages have resulted in new partnerships and grant funds.

Whole farm case studies and focus groups help to identify farmer innovations and experiences that are of value to other farmers, interest groups, and research and education programs. For university personnel, a difficulty with both approaches is gaining institutional rewards for their work. Farmer and citizen knowledge and experience are difficult to quantify and evaluate, and, therefore, the information is not widely accepted as useful when peer reviewed. Because this knowledge represents a nontraditional source of information, it is considered by some to be less valid than other forms of research-gener-

Table 3. Washington State University — Skagit County Cropping Strategies and Water Quality Project: Strengths and difficulties of the focus group process

Strengths	Difficulties
• Challenges academics to de-emphasize their "expert" roles and to strengthen their "learner" roles. The opposite is true for members of the public, who gradually assume more "expert" or "problem solver" roles	• Identifying and involving environmental interest group representatives in the early phases of an agriculture-oriented focus group as shown by token environmental group participation
• Provides an opportunity for growers, scientists and other "interest" groups to share knowledge, experience, expertise and opinions	• Requires an able facilitator or organizer to nurture and support group participants; responsibilities are time consuming and not all people have the needed skills
• Allows group members to develop a broader, deeper understanding of the complexity of western Washington production systems	• Some non-grower members could not understand why they were in the focus group until considerable time had elapsed
• Stimulates participants' curiosity, interest and motivation concerning agriculture, water quality and nitrate leaching	• Subteam members need to learn to share difficulties and responsibilities, to give credit for accomplishments, etc. Requires interteam trust and communication
• Provides an opportunity for coalition building by bringing diverse groups together in a neutral setting	• Can be dominated by a few strong, vocal individuals unless there is a competent facilitator
• Strengthens individuals' problem solving commitments	• Requires considerable time commitment by all team members
• With the services of a neutral facilitator, allows extension and research personnel to participate as focus group members	• Perception on the part of the subteam that focus group members did not have the time to meet face-to-face; participants took part regularly and willingly in spite of numerous community and business responsibilities
• Stimulates a proactive stance among growers concerning a problem that otherwise could have regulatory impact	
• Increases participants' interest in the subject in a nonthreatening atmosphere	
• Diffuses potential conflict among participants holding different beliefs and values	

ated information. However, the involvement of farmers and interest groups increases the likelihood that the information will be applicable to "real world" conditions.

We need to help university administrators, including department chairs, research directors, and deans, to find ways to document and show the value and impact of interdisciplinary work and the potential it offers for reaching a broad base of target audiences. WFCS and focus groups offer a flexible alternative to traditional research and education strategies. Both approaches are valuable tools for understanding sustainable agriculture problems and whole farm systems. The techniques are also useful for building interdisciplinary teams and for strengthening partnerships between the land-grant universities and diverse interest groups.

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Clinton Administration Offers Pesticide Reform, Food Safety Bill

The Clinton Administration, represented by the U.S. Department of Agriculture, U.S. Environmental Protection Agency, and Food and Drug Administration, has proposed legislation to reform the nation's pesticide and food safety laws by amending the Federal Insecticide, Fungicide, and Rodenticide Act, and the Federal Food, Drug, and Cosmetic Act. The legislation incorporates a number of the recommendations made by a 1993 National Academy of Sciences report by "calling for a specific finding that tolerances are safe for infants and children, and adding other safety factors for setting tolerances and documenting more scientific studies to assess children's dietary exposure," according to the Administration.

"The legislation also includes incentives for the development of new alternative pest management materials, focuses federal programs on the research into those alternatives, and rationalizes the registration process so that farmers have access to new tools which pose fewer risks to human health and the environment."

But the Administration eliminated a proposed timetable, included in a draft version of the bill, for farmers to shift to alternative forms of pest control that rely less on chemicals. The current proposed bill endorses integrated pest management but does not say how quickly farmers should adopt the approach.

The bill would set deadlines for removing dangerous pesticides from the market; restrict the ability of industry to justify use of a pesticide based on its economic advantage; and give the FDA the authority to seize or recall food that contains pesticide levels in excess of those set by the regulations. The proposed legislation would abolish the Delaney Clause, which prohibits the presence in processed foods of any traces of pesticide residues or other additives shown to be carcinogenic, and require the EPA to establish a more uniform, health-based standard for all pesticides used on food. That approach would require EPA to take into account only the risks a pesticide poses to human health when establishing tolerances for it, and require pesticide registrants to prove that allowable pesticide residues on food pose a "reasonable certainty of no harm" to consumers.

According to Agriculture Secretary Mike Espy, "With the introduction of this legislative proposal, the Administration is fulfilling its commitment to offer comprehensive reforms to the nation's pesticide laws that further protect the environment and human health while ensuring that farmers will have the pest control tools necessary to produce an abundant and affordable food supply."

The Administration proposal is seen as a compromise between the two other pesticide reform bills already introduced, the Kennedy-Waxman Bill (S.331, H.R.4091) and the Lehman-Bliley Bill (H.R.1627). The Waxman bill, introduced in March, is an updated version of an earlier pesticide reform bill (H.R.872) introduced last year. The Kennedy-Waxman proposal is supported by many environmentalists and pesticide reform organizations; the Lehman-Bliley proposal is generally referred to as the bill favored by industry.

However, the prospects of the Clinton Administration's bill in Congress are "uncertain because neither industry nor environmental groups support the Administration's approach," according to *The New York Times*. That view was also taken by Greenwire, a daily environmental news service, which said, "All sides — enviros, farmers, and chem industry officials — criticize parts of the plan, creating doubts that the bill will be passed this year."

A framework for evaluating the sustainability of agricultural production systems

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Abstract. *Sustainable agriculture has gained acceptance as a conceptual approach for shaping farming systems of the future. All definitions of sustainable agriculture include food productivity, food safety, resource protection, quality of life and environmental quality. However, the sustainability of a wide range of farming systems has been judged only subjectively. Currently there are no scientific criteria to evaluate the sustainability of a specific farming system. We propose a framework for evaluating the relative sustainability of a farming system using nine attributes: profitability, productivity, soil quality, water quality, air quality, energy efficiency, fish and wildlife habitat, quality of life, and social acceptance. Each attribute is scored and then weighted in a way that is subjective and dependent on the judgment of the evaluating team, but that must be expressed numerically. The scoring must be based on quantifiable constraints within each attribute. Constraints can be quantified by direct measurement, which is already true for those related to profitability, productivity, water quality and energy efficiency. Constraints that are not readily measurable will need other evaluation techniques, including expert opinion and computer simulation models.*

Key words: sustainable agriculture, productivity, soil erosion, simulation models

Introduction

Although the sustainability of agricultural production systems has received much attention, there is no practical method for evaluating it, a need that we try to address here. The discussion will center on farming systems that are typical in the U.S., but the method should apply anywhere. Instead of putting forth a new definition of sustainability, we concentrate on the common elements usually associated with sustainable agricultural systems (e.g., Senanayake, 1991; Anderson and Lockeretz, 1992; Neher, 1992). Most definitions agree that sustainable practices should do the following:

- provide an abundant and safe supply of food and fiber to meet society's demands;
- preserve the natural resource base, aiming for sound and effective environmental stewardship;
- maximize the quality of rural and urban life;
- maintain the profitability of farms while making farming more compatible with public standards of environmental quality.

Combining these elements, the American Society of Agronomy has adopted the following definition (Schaller, 1990):

> Sustainable agriculture is one that, over the long-term, enhances environmental quality and the resource base on which agriculture depends, provides for basic human food and fiber needs, is economically viable, and enhances the quality of life of farmers and society as a whole.

The elements listed above provide general goals and guidelines for shaping the farming systems of the future. These goals can be translated into specific objectives amenable to evaluation as we discuss later. The key need is to develop simple but effective tools for such evaluation.

Conventional agriculture in the U.S. includes capital-intensive monocultures; continuous cropping; substantial reliance on manufactured inputs such as fertilizer, pesticides, and machinery; and heavy dependence on credit and government subsidies (Neher, 1992). Conventional agricultural systems in the U.S. are increasingly perceived as unsustainable (e.g., Parr et al., 1990). Agriculture often is identified as the largest nonpoint source of surface water pollution, and pesticides and nitrate from fertilizers have been detected in the groundwater in many agricultural regions. Agricultural soils are being eroded, with their fertility and physical and biological conditions degraded (National Research Council, 1989).

In contrast, many alternative farming systems have been proposed that are assumed to be sustainable. These systems are categorized using various labels, such as *organic farming*, *alternative agriculture*, and *low-input/sustainable agriculture*. However, the alternative to conventional farming in the U.S. is not a single set of practices but rather an array of farming systems tailored to particular conditions. The effectiveness of most still must be evaluated, but there is no reliable and unbiased

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evaluation method. We need a quantitative, practical, decision support system for evaluating the sustainability of agricultural production systems.

Sustainable vs. Unsustainable: An Evaluation Problem

Assessing the sustainability of agricultural production systems is not easy. On one hand, the evaluation is likely to be influenced by the evaluating team's conceptual definition of sustainability. On the other hand, sustainability has no single, summary indicator (Flora, 1992), and many different factors must be considered in the evaluation.

Dunlap et al. (1992) listed 14 possible components of sustainability in a questionnaire mailed to agricultural faculty members at a land-grant institution and a statewide (Washington) sample of farmers. They found large differences in what components the respondents viewed as "definitely necessary" for sustainable agriculture. Faculty members were more likely to emphasize making agriculture ecologically sustainable (enhancing the environment and wildlife habitat, increasing agricultural diversity, reducing agrochemical use, reducing energy use, etc.). Farmers, in contrast, were more likely to emphasize economic and social sustainability (improving the farm economy, improving the health and well-being of rural residents, revitalizing rural areas, decreasing the complexity of the food system, increasing the number of farmers, etc.). There were large differences across academic disciplines, with faculty members in more production-oriented disciplines holding narrower definitions of sustainability than those in other disciplines (Dunlap et al., 1992).

Another example of ambiguities in the conceptual definition of sustainability is the difficulty of classifying farmers as conventional or sustainable. Youngs et al. (1991), in a study conducted in North Dakota, found only slight correlations among the results of nine classification schemes. There also is a mismatch between research on sustainable agriculture and the rhetoric of sustainability (Anderson and Lockeretz, 1992). Of the 122 research projects analyzed by these authors, almost all covered techniques that potentially can conserve nonrenewable resources and reduce environmental pollution, but most did not show the broad scope emphasized in current writings about sustainable agriculture.

Identifying useful indicators of sustainability is not simple. Many indicators can be listed, but we cannot necessarily quantify and score them. On the other hand, the ability to assign priorities among these indicators is constrained by how the evaluating team perceives sustainability. To make progress in implementing new practices and evaluating their potential sustainability, we recommend deemphasizing the philosophical and broad conceptual issues about sustainability. Instead, emphasis should be on actual use of innovative systems aimed at long-term sustainability in a "common sense" definition, and on developing practical, quantitative tools for quickly assessing in advance the likely sustainability of specific farming systems.

A step in this direction is exemplified by the Agroecosystem component of the EPA Environmental Monitoring and Assessment Program (EMAP), which is developing a system-level approach to monitor the sustainability of agroecosystems on a long-term regional or national scale. One objective of the program is to estimate the condition of U.S. agroecosystems as a baseline against which we can compare future conditions with statistical confidence (Neher, 1992). A pilot study has been started in North Carolina in cooperation with the U.S. Department of Agriculture's National Agricultural Statistics Service and Agricultural Research Service. Indicators are being developed to address five characteristics: crop productivity, soil quality, water quality, agricultural chemical use, and land use (EPA, 1992). Although commendable, this monitoring effort is a long-term endeavor whose practical impact will not be felt for many years. On-farm sustainable agriculture research has and will continue to provide information for evaluating specific farming systems, although a change in the traditional approach seems necessary for a meaningful contribution in this area (Taylor, 1990). As with the EMAP program, research must be conducted for many years before definitive conclusions can be reached.

A Framework for Evaluating Sustainability

We can make progress in developing tools for evaluating sustainability if we first focus on identifying systems that clearly are unsustainable, and then build up our ability to identify those that appear more sustainable. Constraints to sustainability used for this purpose must be readily measurable, predictable with simulation modeling or other computer-aided techniques, or estimable through expert opinions.

Fig. 1 shows a proposed scheme for evaluating the sustainability of a farming system. This scheme includes a list of attributes of sustainability and a list of constraints for each attribute. A system is evaluated by assigning weights to each attribute, scoring the attributes of the proposed system based on specific constraints (see below), and then combining the weights and scores to produce a figure of merit. Some weights may be difficult to choose, but others have been set by society. For example, a system that is perfectly sustainable in all attributes except profitability would not be sustainable. Similarly, a system that fails to comply with water or air quality laws would not be sustainable, no matter how good it might be on other counts, because a sustainable system must not break the law. Weights in such cases need to be set so that an unsatisfactory score rejects the whole system. If all attributes are within the satisfactory range, the scores need to reflect the relative merit of each system. This approach does not allow us to determine the sustainability of the farming system in absolute terms. Instead, it compares the relative sustainability of different systems.

Quantification of Constraints

A key element in the proposed scheme is quantification of the specific constraints within each attribute. The constraints listed in Fig. 1 are only suggestions; items could be added or deleted. However many constraints are included for each attribute, they must be scored individually. In scoring constraints to sustainability, it also is im-

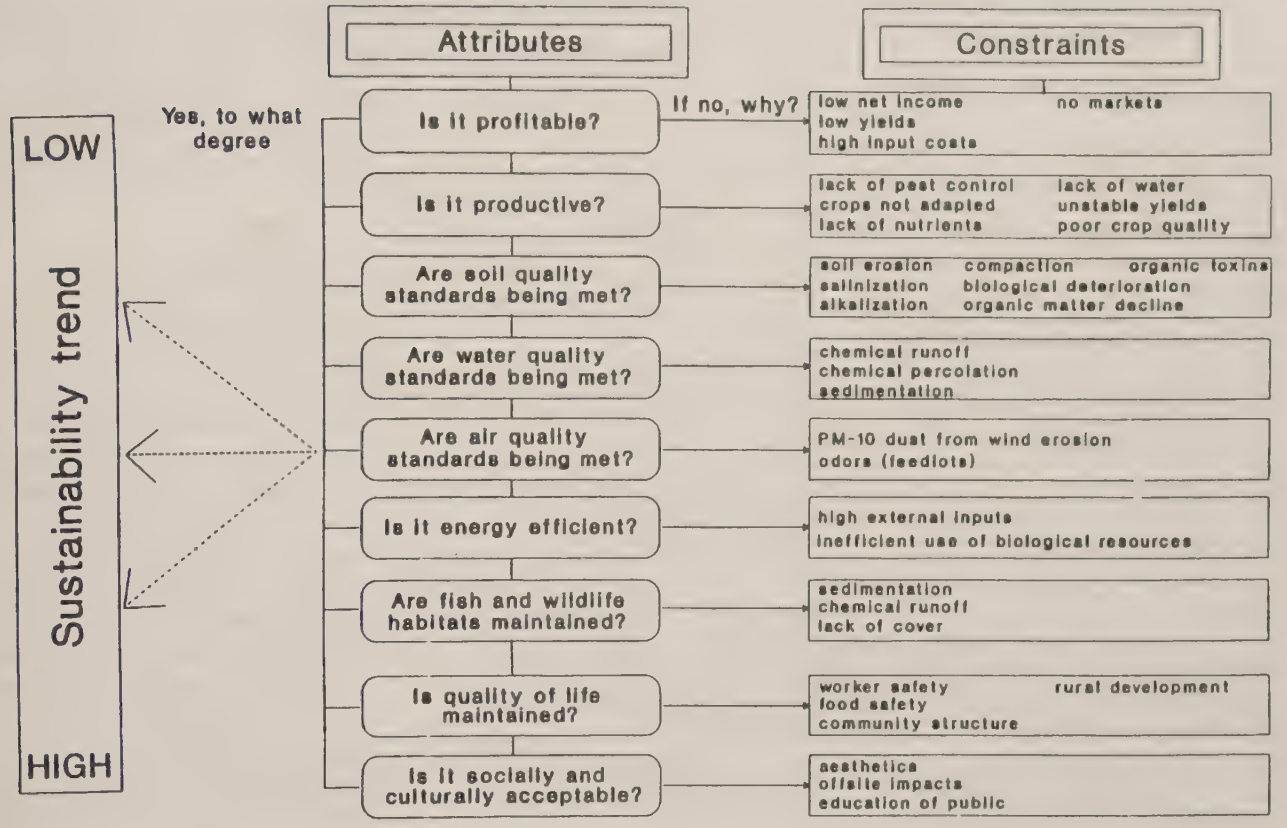

Figure 1. Evaluation diagram of farming system sustainability.

portant to bring in long-term effects. For example, in analyzing yield constraints, information on current yields will be valuable, but the long-term projection of yield levels will determine the score for this constraint. Our approach is based on the concept that any constraints chosen for the evaluation scheme must be amenable to numerical definition (e.g., dollars of net income, Mg/ha/year of soil erosion, ratio of energy output to energy input, etc.). This is easier with biophysical and economic constraints than social constraints. However, constraints that are not quantifiable are of little use. A list of quantifiable constraints often found in the literature is given in Table 1.

Quantification of constraints is not easy. Some can be quantified by direct measurement. However, in many situations, measurements are not feasible because of limits in time or resources. Also, projecting the long-term rate of change of individual constraints poses additional challenges. Two other options are available: expert opinion and simulation modeling. Although they may not be as reliable as direct measurements, when they are used with judgment they can produce satisfactory results. Because the objective is to estimate the relative sustainability of farming systems, great accuracy may not be required.

Constraints associated with productivity, soil quality, and water quality typically are quantifiable using simulation models. Others, such as those related to profitability, air quality, and maintenance of fish and wildlife, also can be handled by modeling. An advantage of simulation models is their ability to compare various management scenarios over a long time series (50 to 100 years or more) using actual or generated weather data.

An example of the results that can be obtained with simulation modeling is given in Figs. 2, 3, and 4, showing the crop yield, residue cover, and the C-factor (one of six factors in the Universal Soil Loss Equation that determine soil erosion by water). These results are from a 100-year simulation of a wheat/barley/pea rotation in Pullman, Washington under conventional and conservation tillage (van Evert, 1992). Simulated yields of wheat were higher under conservation tillage than under conventional tillage (Fig. 2), while tillage negligibly affected the simulated yields of barley and pea (not shown). The most important effects of conservation tillage were a dramatic increase in the fraction of soil covered by crop residues (Fig. 3) and a decrease in the C-factor (Fig. 4), the latter implying a proportional reduction in soil erosion by water. The ability to generate both expected values and probability distributions allows us to assess both the typical response of the system and the risks.

Constraints also can be quantified using expert opinions. Weighting how much each constraint contributes to the attribute score and how much each attribute contrib-

Table 1. Measurable constraints on sustainability, by assessment elements.

Profitability

Decreasing farm income
Increased dependence on credit

Productivity

Decreasing yields

Soil quality

Increasing or steadily high erosion rates
Decreasing organic matter content
Decreasing cation exchange capacity
Increasing salinization of soils
Increasing alkalization of soils
Decreasing infiltration
Decreasing water holding capacity
Decreasing earthworm activity

Water quality

Increasing or high rates of nitrate leaching beyond root zone
Increasing or high rates of pesticide leaching beyond root zone
Increasing or high rates of nitrates and toxic organics in drinking waters
Increasing or high rates of chemical loading into surface streams
Increasing BOD in surface streams
Increasing coliform counts in surface streams
Increasing eutrophication of water bodies

Air quality

Increasing or steadily high soil erosion rates by wind
Increasing fine particulates (diameter <10μ; PM-10 dust index)
Increasing odor intensity

Energy efficiency

Increasing or high dependence on fossil fuel use
Decreasing output/input energy ratio

Wildlife habitats

Increasing lake and pond sedimentation
Decreasing wildlife populations
Decreasing adequacy of wildlife habitat

Quality of life

Increasing or high rates of undesirable chemicals in agricultural products
Decreasing standard of living in agricultural communities
Decreasing income level

Social acceptance

Increasing complaints regarding food safety
Increasing complaints regarding quality of drinking water
Increasing concern regarding long-term adequacy of food supply
Increasing complaints regarding health threats from agriculture

utes to the farming system's overall score requires subjective judgment by the evaluating team. Despite this subjectivity, the framework presented here provides a rational approach to evaluating numerically the relative sustainability of farming systems.

Final Remarks

This framework for evaluating the sustainability of agricultural systems is preliminary, but it incorporates the necessary elements and procedures to allow progress toward comparing the relative sustainability of many production systems in use today or proposed for the future. Refinements are required, particularly regarding weighting of attributes and the selection, quantification, and weighting of constraints. The approach is amenable for a computer-assisted decision support system, where expert opinions and dynamic simulation models can be integrated as supporting tools. The continued development, improvement, and testing of agricultural simulation models must be encouraged because often they are the only way for long-term quantification of constraints to sustainability.

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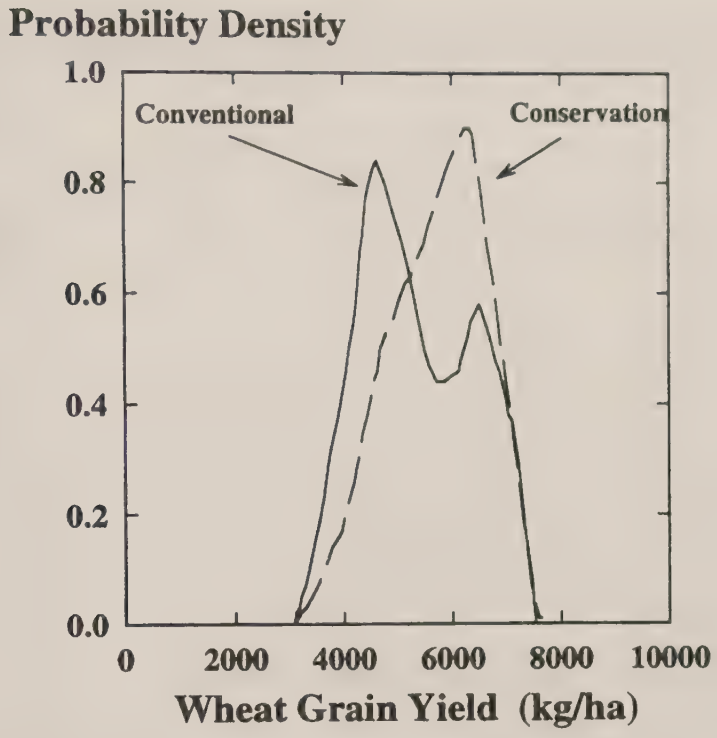

Figure 2. Probability density function of simulated wheat yield under conventional and conservation tillage in Pullman, Washington (from van Evert, 1992).

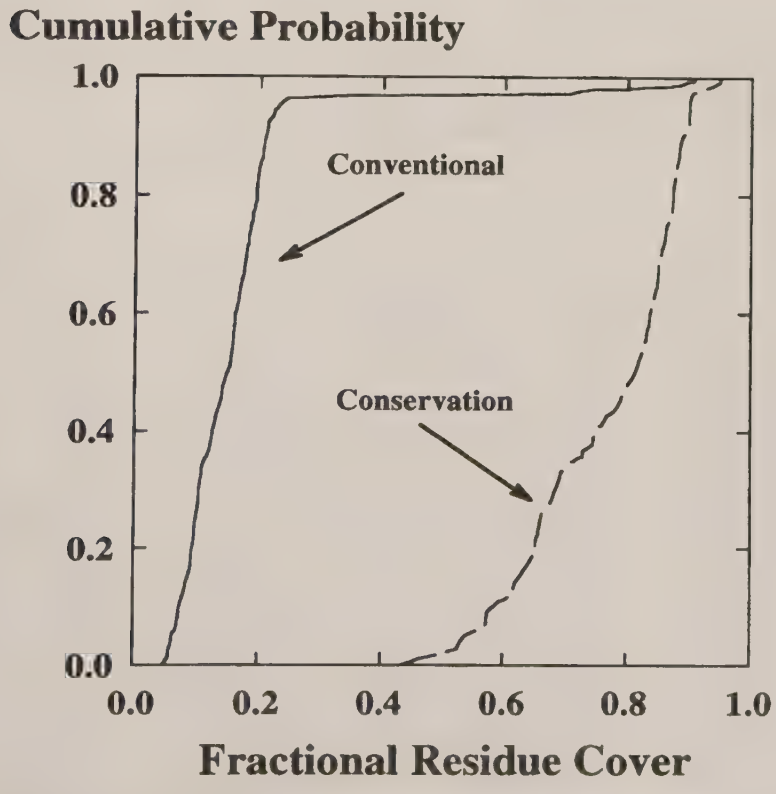

Figure 3. Cumulative probability of the simulated fractional residue cover on November 1 under conventional and conservation tillage for winter wheat/spring barley/spring pea rotation in Pullman, Washington (from van Evert, 1992).

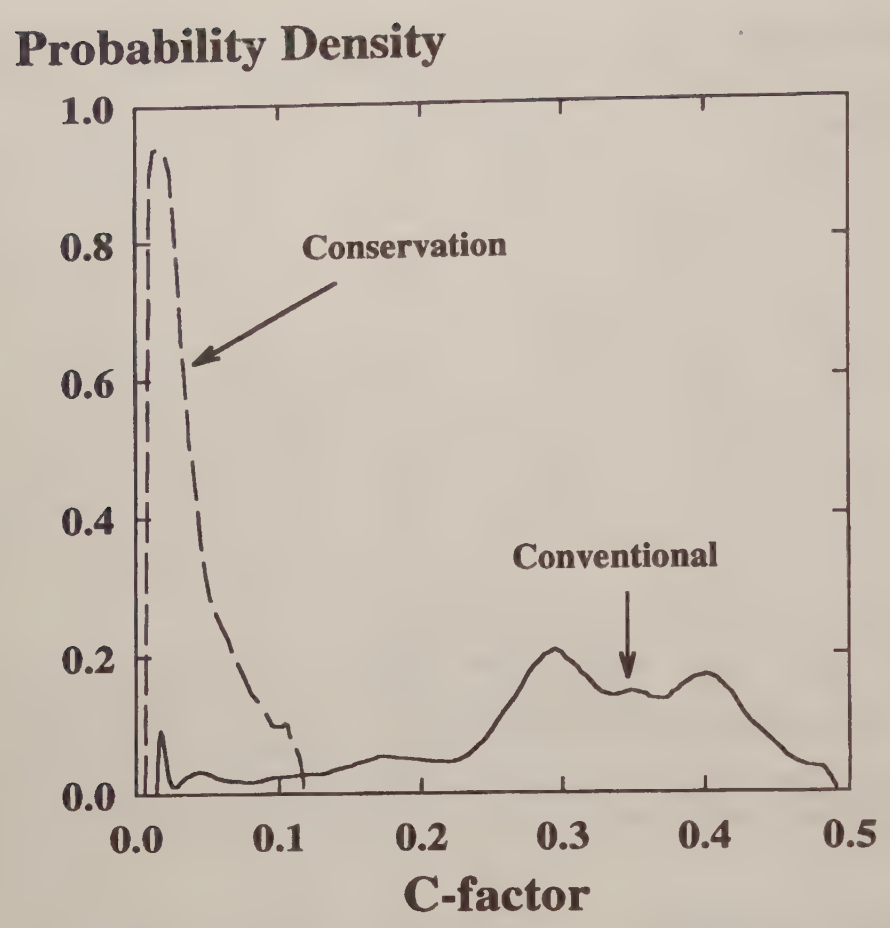

Figure 4. Probability density function of the simulated C-factor in the Universal Soil Loss Equation in winter wheat/spring barley/spring pea rotation under conventional and conservation tillage in Pullman, Washington (from van Evert, 1992).

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Farmers Increasingly Ask ATTRA for Sustainable Ag Info

Farmers who are increasingly interested in sustainable agriculture are the primary users of the technical assistance service set up by Appropriate Technology Transfer for Rural Areas (ATTRA), in Fayetteville, Arkansas. According to figures compiled by ATTRA for January 1 to March 31, 1994, almost 70% of ATTRA cases came from farmers. During that same time, the types of alternative production information requested from ATTRA by those cases were dominated by general production, 39.1%; market/finance, 13.5%; soil fertility, 12.9%; pest control and equipment/building, 8.2% each; 4.6%, general LISA (SARE); 6.9%, other general; and 6.6%, other production.

Categorized by production enterprise type, 27% of the ATTRA information requests came from farmers of diversified crops; 23.5%, livestock/fish; 19.1%, fruit crops; 13.7%, vegetable crops; 5.6%, field crops; and 11.1%, other crops. "The increased interest in sustainable agriculture is clearly reflected in the number of information requests ATTRA is receiving," according to Robert J. Gray of ATTRA, who estimates the service will respond to 14,000 inquiries this year. "Most of these requests are from individual farmers who are incorporating sustainable agriculture practices into their farming operations," Gray said.

Nutrient Management Training Helps Farmers Protect Chesapeake Bay

A new Model Bay Area Nutrient Management Training and Certification Program, provided by the Chesapeake Bay Program, is the first multi-state effort to standardize nutrient management training and certification. It provides a framework to guide Maryland, Virginia, and Pennsylvania in their efforts to enlist, train, and certify individuals from the private and public sectors to write nutrient management plans for farms, to help protect water quality. For a copy of the training and certification document, call Kate Naughten or Elliott Finkelstein, Chesapeake Bay Program Communications Office, 1-800-523-2281.

RESOURCES

Farm Animals in the Making of America ($14), Farm Inventions in the Making of America ($14), and *Farm Power in the Making of America* ($19), three books by the late Paul C. Johnson, have been republished and are available separately or as a set for $45, plus $3/book or $5/set postage and handling, from Institute for Agricultural Biodiversity Books, 2132 Pole Line Rd., Decorah, IA 52101; Iowa customers, please add 5% sales tax.

National Sustainable Options Hotline, a service of the Center for Rural Affairs and the Midwest Sustainable Agriculture Working Group, is available to help farmers and ranchers explore options under USDA sustainable agriculture, water quality, conservation, and wetlands reserve programs; the number is (402) 491-3620; "Farm Program Options Guide," prepared by the Sustainable Agriculture Working Group, is also available for $5 from the Center, P.O. Box 406, Walthill, NE 68067.

1993 Pacific Northwest On-Farm Test Results is available from Baird Miller, Department of Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420.

A Pond Owner's Management Guide is $7 from the Kerr Center for Sustainable Agriculture, Attn: Lara Ervin, P.O. Box 588, Poteau, OK 74953.

Food for the Future: Conditions and Contradictions of Sustainability, edited by Patricia Allen, 328 pages, includes 12 chapters by 15 authors; copies are $39.95 from John Wiley & Sons., Inc., 605 Third Avenue, New York, N.Y. 10158-0012; 1-800-225-5945.

The Dairy Debate, an interactive computer program developed by the Sustainable Agriculture Research and Education Program for exploring the questions posed by BGH/BST, is available free through the Internet system by sending an e-mail request to rjzomer@ucdavis.edu; or send a blank, high-density 3 1/2" diskette and a return label, or $5 check payable to UC Regents to Dairy Diskette, SAREP, University of California, Davis, CA 95616.

Water-Efficient Landscaping: A Guide for Utilities and Community Planners, publication W94-8, is $10 from Scott Chaplin, Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass, CO 81654-9199; (303)927-3851.

Dollars and Sense, A Handbook for Seasonal Grass Dairying is $17.95 plus $3.50 shipping/handling from Stockman Grass Farmer Magazine, P. O. Box 9607, Jackson, MS 39286-9607; 1-800-748-9808.

Understanding the Human Element in Agricultural Resource Conservation is available from Soil and Water Conservation Society, 7515 Northeast Ankeny Road, Ankeny, IA 50021-9764; (515)289-2331.

1994 catalog of the *MidWest Plan Service*, Iowa State University, is available from MWPS, 122 Davidson Hall, ISU, Ames, IA 50011-3080; (515)294-4337 or 1-800-562-3618.

1994 National Organic Directory is $34.95 plus $4 shipping from Community Alliance with Family Farmers, P.O. Box 464, Davis, CA 95617; (916)756-8518 or 1-800-852-3832.

Future Harvest: Teaching Manual is a companion to *Future Harvest*, by Jim Bender; contact University of Nebraska Press, 312 N. 14th St., P.O. Box 880484, Lincoln, NE 68588.

Managing Global Genetic Resources: Agricultural Crop Issues and Policies is one volume from a four-volume series from the Committee on Managing Global Genetic Resources: Agricultural Imperatives, National Research Council; it is 480 pages, hard cover, $49.95 plus $4 shipping/handling from National Academy Press, 2101 Constitution Ave., NW, Lockbox 285, Washington, D.C. 20055; 1-800-624-6242.

Free listings of *community supported and biodynamic farms and gardens* are available by calling 1-800-516-7797; other resources are available from the Bio-Dynamic Farming and Gardening Association, P.O. Box 550, Kimberton, PA 19442, (610)935-7797.

The Caretaker Gazette, which helps landowners and caretakers find each other, is $18 a year for six issues from The Caretaker Gazette, 221 Wychwood Road, Westfield, N.J. 07090; (908)654-6600.

A Sustainable Agriculture Resource Guide for Oregon and Washington, (EM8531), 220 pages, is $9 from Publications Orders, Agricultural Communications, Oregon State University, Administrative Services A422, Corvallis, OR 97331-2119.

The Sustainable Agriculture Directory of Experts ($14.95), *The Showcase of Sustainable Agriculture Information and Educational Materials* ($4.95), and *Managing Cover Crops Profitably* ($4.95) are available from the Sustainable Agriculture Network, Sustainable Agriculture Publications, Hills Building, UVM, Burlington, VT 05405; (802)656-0554.

Integrated Pest Management for Strawberries, (#3351) is $30, payable to UC Regents, from ANR Publications, Dept. NR, University of California, Oakland, CA 94608-1239; (510)642-2431; or Agricultural Information and Publications Office, UC Davis, (916)757-8930.

Protect Your Groundwater: Education for Action, 64 pages, is $6.95 plus $3.50 shipping/handling from Publications Department, League of Women Voters, 1730 M St., NW, 10th floor, Washington, D.C. 20036; (202)429-1965.

Whole Farm Case Studies of Horticultural Crop Producers in the Maritime Pacific Northwest is available from Publications Orders, Agricultural Communications, Oregon State University, Administrative Services A422, Corvallis, OR 97331-2119; (503)737-2513.

Pesticides and Groundwater: A Guide for the Pesticide User is $4, payable to NRAES, from the Northeast Regional Agricultural Engineering Service, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, N.Y. 14853-5701; (607)255-7654.

Taking Stock: The North American Livestock Census is $14.95 plus $2 shipping from American Livestock Breeds Conservancy, P.O. Box 477, Pittsboro, N.C. 27312; (919)542-5704.

Case studies of integrated/whole farm system designs: Field-scale replicated IPM trials

Frank L. Young, Alex G. Ogg, Jr., and Robert I. Papendick

Abstract. *A 6-yr interdisciplinary field project using large plots was initiated in 1985 to assist Pacific Northwest growers in developing an integrated pest management system to control weeds, reduce erosion and grow crops profitably. Run by a network of 10 to 14 scientists from eight disciplines supported by five agencies, the project showed that well-managed conservation tillage systems had a higher average profit and lower economic risk than traditional conventionally tilled systems. Information was disseminated successfully to user groups by field days, plot tours and an educational video. Organizational strategies included an interdisciplinary design with three levels of objectives. Cooperating scientists were invited to participate in writing the proposal and followed strict field protocols and attended mandatory organizational meetings. This long-term study used large machinery, went beyond the transitional stage and allowed treatments to mature. Limitations included the restricted number of experimental variables, the location of the plots, the large labor force required, and publication decisions.*

Key words: crop rotation, economics, integrated pest management, interdisciplinary, long-term research, systems research, tillage systems, weed management

Introduction

From 1985 to 1991, a field study was conducted to examine crop production systems in the dryland winter wheat growing region of the Pacific Northwest (PNW). Production variables included: conservation or conventional tillage; monoculture wheat (*Triticum aestivum* L.) (winter wheat, winter wheat and spring wheat) or a 3-yr rotation of winter wheat, spring barley (*Hordeum vulgare* L.), spring dry pea (*Pisum sativum* L.); and minimum, moderate or maximum weed management levels (Young, F.L., et al., 1994). Winter wheat in the conservation tillage system (a combination of no-till and reduced tillage) was planted no-till following spring pea and spring wheat. The chisel plow was the primary tillage implement for subsequent crops. The primary tillage implement for the conventional system was the moldboard plow, unless wheat followed pea, for which the field was disked. Monoculture wheat was chosen as one crop production system because crop subsidies, farm economics and the high wheat yielding capability of the Palouse Region dictate that wheat be grown as often as possible. We chose the 3-yr rotation because it greatly reduces root diseases of wheat (Cook and Veseth, 1991). However, the population dynamics of insects and weeds and the economics and productivity of barley and peas in this system have not been examined (Young, F.L., et al., 1994).

Three weed management levels were provided by different combinations of tillage and rates and kinds of herbicides (Young, F.L., et al., 1994). Minimum weed management was a short-term, low input system; moderate was the management recommended by weed extension specialists; maximum was a high input system, although it never had the economically unfeasible objective of 100% weed control. Weed levels and the control of diseases and insects were managed by scouting, using economic thresholds, and choosing pesticides that were least environmentally toxic. Land requirements precluded having plant pathogens and insect control as individual variables.

Project Objectives

Many research strategies can be used to discover, implement and integrate improved technologies into crop production practices that will maximize profits, protect natural resources and limit damage to the environment. In 1982, scientists and National Program Leaders from USDA-ARS began drafting a proposal to conduct integrated pest management research for conventional and conservation tillage systems in the Palouse region of the PNW, one of the six most erodible agricultural regions in the United States. Typical annual erosion rates in this productive region range from 20 to 40 t/ha, but erosion may reach 200 to 450 t/ha on some slopes in a single winter (U.S. Dept. of Agriculture, 1978). The severe sheet, rill and tillage erosion is attributed to the high winter precipitation, steep slopes, and winter wheat management practices that leave the soil bare and unprotected over winter (Papendick et al., 1983). Soil erosion can be re-

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duced at least 35% with conservation tillage (Frazier et al., 1983). Conservation tillage is recognized as the most economical and practical method for erosion control, but its usefulness is limited by weed control problems in the annual-cropped, winter wheat growing areas.

The large-scale, field-size research project was started in 1985 to apply an IPM systems approach for conservation crop production in the PNW. It complemented the more component-oriented erosion research project called STEEP (Solutions to Environmental and Economic Problems) being conducted in Washington, Idaho and Oregon (Michalson and Papendick, 1991; Papendick et al., 1991). The IPM research had two objectives: to examine the effects of crop rotation, tillage and intensity of weed control on weed, insect and pathogen infestations and their impacts on yield and quality of cereals and grain legumes; and to use the information to develop economically feasible and environmentally sound crop management systems that effectively prevent erosion and control pests. To accomplish these objectives, we studied a wide range of variables under the latest production technology, including: populations of weeds, earthworms, insects, pathogens, and soil microbes; plant nutrient status; soil water content; residue management; and grain yield and quality. Up-to-date and effective technologies integrated in this study included best crop varieties, optimum seeding rates and dates, and fertility and tillage management.

The project investigated questions from growers, the Soil Conservation Service (SCS), and Extension Service on farming practices that could protect the soil adequately without reducing growers' profits. The research objectives were formulated from the mission and goals of the USDA-ARS Weed Science and Land Management Units (Pullman, Washington) and the National IPM/PT (Pilot Test) Projects (Beltsville, Maryland). They were based on regional and national priorities, that is, to conduct systems research to help growers in developing a management system to control weeds and reduce erosion while growing crops profitably.

Significant Project Outcomes

At the end of the 6-yr study, the two major objectives were met and a profitable, grower-adaptable conservation production system was presented at a field day during the last year (Boerboom and Young, 1991). The most successful crop production system was a 3-yr rotation of winter wheat, spring barley, and spring dry pea grown with conservation tillage and effective weed control (Young, D.L., et al., in press; Young, F.L., et al., 1994). This system, which was highlighted on the field day, demonstrated the effective use of non-chemical cultural practices (crop rotation and limited tillage) to control winter annual grass weeds and soilborne pathogens (Young, F.L., et al., 1994). Winter wheat yields were highest in the 3-yr rotation compared with yields in continuous wheat (Table 1) (Young, F.L., et al., 1994). Also, winter wheat following spring pea and spring wheat yielded more in the conservation tillage system (no-till) than in the conventional system. Tillage operations and subsequent soil erosion were markedly reduced, especially in no-till winter wheat after pea and in spring dry pea, where tillage operations in the conservation system decreased by more than half compared with the conventional system used by farmers when the project began in 1985 (Young, F.L., et al., 1994; in press). Pea yields in the conservation system were equal to or greater than yields in the conventional system, and the conservation system required very little additional herbicides to control weeds (Young, F.L., et al., in press).

This was the first research project in the PNW to show that conservation farming was more profitable and less risky than conventional practices (Young, D.L., et al., in press). The extensive data from this project is being used for predictive modeling for profitable and environmentally sound crop production systems. This is in contrast to most crop/weed models, which usually are not holistic and which collect and assess data from only one weed in one crop. While we were building our predictive model, it was evident that our information still had many gaps. For example, we lacked information on production and germinability of weed seeds. Our project can serve as a model for other pest control problems in a whole-system interdisciplinary approach to research.

Technology Transfer

We transferred the information collected in the IPM project by several means (Table 2). Of these, the most successful was field days. During the six years of the project, USDA-ARS and Washington

Table 1. Average winter wheat yield (kg/ha) in response to tillage systems and rotation position.[1]

Rotation position[2]	Tillage system[3]	
	Conservation	Conventional
WW/SP	6510a ***	5895a
WW/SW	5305b **	4875b
WW/WW	4465c	4505c

[1] Data reprinted with permission of F.L. Young and *Agronomy Journal*.

[2] WW/SP = winter wheat after spring pea in winter wheat, spring barley, spring pea rotation; WW/SW = winter wheat after spring wheat in winter wheat, winter wheat, spring wheat rotation; WW/WW = winter wheat after winter wheat in winter wheat, winter wheat, spring wheat rotation.

[3] Within tillage systems, rotation positions with different letters are significantly different ($p<0.05$); ** and *** indicate significant differences at $p<0.01$ and $p<0.001$, respectively, between tillage systems within rotation position.

State University hosted three field days. The first (1987, second year) introduced the project and scientists, identified objectives and explained the rationale of the study. The second (1989, fourth year) was a research progress report. The last field day (1991, sixth year) integrated all disciplines and production factors responsible for the successful conservation cropping system. Interest in this project was shown by the fact that over 300 people attended this field day. Also, informal IPM tours were held at the request of commodity groups (National Pea and Lentil Commission), college faculty members, researchers, farmers and dignitaries from many countries, and personnel from national agencies, including USDA-ARS, ASCS, SCS and the Conservation Technology Information Center.

Another successful method of technology transfer was a video tape (Boerboom et al., 1992) that summarized the research project and described the results and the factors responsible for the success of the 3-yr conservation tillage rotation. The goal of the video was to inform growers of the economic and resource benefits of conservation tillage.

The intended audience for this information included growers, agricultural scientists, research administrators, public policy makers, bankers, loan officers, townspeople, conservationists, agroindustry personnel, consumers and international scientists. Examples of those benefitting from this project include: county extension agents who help growers to incorporate the procedures, methods, and ideas from this study into area production systems; SCS, which is formulating farm plans based on the IPM information to meet conservation compliance provisions of the 1985 and 1990 farm bills; and agricultural economists who are evaluating the economic risks and profitability of the various agroecosystems.

The Project's Integrated, Whole Farm Orientation

The backbone of the this project was the integrated approach to systems research on a large tract, in contrast to traditional small-scale component research to solve practical, applied production problems. We examined how management practices influence a complex of on-farm production problems. From the initial formation of the proposal, scientists with proven expertise in their respective disciplines were chosen as cooperators. Depending on the phase of the project, from 10 to 14 scientists from eight disciplines (Table 3) were actively involved in planning, carrying out, and analyzing the research. Several agencies were involved, including USDA-ARS, Washington State University, University of Idaho, O.A. Vogel Wheat Research Fund and the Whitman County (Washington) Cooperative Extension Service.

Table 2. Methods of technology transfer of IPM information.

Field Days	Presentations
IPM Plot Tours	Bulletins
Newspaper/Magazine Articles	Videos
Radio Interviews	Manuscripts

Problems and Limitations of the Project

Experimental constraints

We encountered several problems and limitations during the planning, designing and implementation of the field research and subsequent dissemination of the information. The topography and large land requirement restricted the number of experimental factors that could be examined. The final project, encompassing 32 ha (including non-plot ground) and 144 subplots examined two tillage systems, two 3-yr crop systems and three weed management levels (Young, F.L., et al., 1994). The initial proposal had included an additional tillage regime and two fertility rates (recommended and 50% of recommended), which would have increased the number of subplots to 432. This would have been physically and economically impossible. Because of the land limitation and unsure funding beyond six years (two complete cycles of each 3-yr cropping system) no long-term rotations were included, such as alfalfa (for harvest). Also, only one rate of nitrogen was applied to winter wheat regardless of tillage system and rotation position (following pea, spring wheat, and winter wheat). The problem of a limited number of variables was partly overcome by including two smaller-scale satellite studies that examined continuous no-till systems and various fertility rates.

We also encountered problems with the location and layout of the experiment. Because of plot size, the experimental design, and the amount of land available, plots were laid out generally in an East-West direction, which confined tillage operations to the same direction with no perpendicular or diagonal tillage. After several years, this caused small ridges and valleys to be formed in the conventionally tilled systems, and may have prevented optimum incorporation of herbicides and fertilizer. Ideally, the study should have had uniform replications and soil depth. In reality, three of the four replications had similar soil depths and aspects. This caused the weed species and populations to be different on the cool, moist north slope compared with the warm, dry south slopes. The experimental site was leased from a local farmer, and we could not allow perennial/noxious

Table 3. Disciplines involved on the long-term IPM project for wheat production in the PNW.

Weed Science	Agricultural Engineering
Soil Science	Agricultural Statistics
Plant Pathology	Agricultural Economics
Entomology	Cooperative Extension

weeds to grow undisturbed, which limited the information collected on these species.

To maintain the cohesiveness of the study over its duration, the researchers and the project leader did not often deviate from the initial objectives and major management operations. Numerous changes would have converted the study into a series of short-term experiments stretching over a long time. For example, it became obvious to the weed scientists that the maximum level of weed management probably was not required after four or five years. Thus we may have overestimated the operating expense of this system compared with a flexible system. However, we maintained the continuity and comparability of all systems.

Publication and professional problems

A second major area of concern in conducting long-term research is publications. The authorship of each proposed manuscript, including the order of the names, must be decided at the proposal stage. A meeting should be held early in the project to allow all cooperating researchers to list their proposed manuscripts, author lists, and journals. This process will eliminate later dissension and ill-feelings.

Several publication problems unfolded at the conclusion of the project. When "first wave" component manuscripts were in various stages of development, authors often said "unpublished data" or "personal communication" to support their data. Many journals discourage this, but the author does not want to jeopardize other cooperating scientists from publishing their data. Another question that may face scientists is "Do I publish the results first in peer-reviewed journals or extension bulletins?" From a professional standpoint, journal publications receive priority; however, the study was conducted to solve the practical problems of the area's producers. These users usually demand immediate results and information. Another problem was motivating cooperating scientists to publish after the project was concluded. Often, graduate students conducted thesis research on the project and then left without completing manuscripts, which delayed publication. Similarly, scientists are no longer being funded by the project and have become involved in new areas of research.

The two major publication problems associated with long-term field studies are professional advancement and recognition (Hildebrand, 1990), and integrating the results into a single, concise manuscript or book. In this type of study, scientists do not advance rapidly because of the long interval before publication. This affects the project leaders even more than the cooperating scientists. Project leaders must greatly reduce their other research to meet the demands of long-term, large-scale field studies.

This in turn leads to the second problem. In the rush to garner professional recognition, scientists will quickly publish single discipline manuscripts that will be "hidden" in their favorite journals. The reader must assemble the information by collecting individual manuscripts and reviewing all the literature citations. To alleviate this problem, a single publication integrating all the project's findings, interactions and procedures must be published.

Project Strengths

Organizational structure

The success and scientific strengths of the project can be attributed to its organizational and operational structures (Table 4). Cooperating scientists were invited to participate actively, starting with the initial proposal writing. Getting the agricultural statistician and economist involved early helped insure that the experiment was designed properly and that relevant data were collected. The scientists conducted their own literature searches and wrote the introduction, research methods and objectives for their respective disciplines.

To maintain researchers' interest and insure that they were doing more than just monitoring and consulting, the objectives were structured on three levels, reflecting the project's, disciplines', and the researchers' objectives, respectively. For example, in weed science, the project objective was to investigate the interaction of crop production variables with pest incidence and the resulting effects on crop yield. The discipline's objective was to establish three biologically and economically different weed populations. The last level of objectives reflected the individual researcher's interests. In the case of the weed scientists, individual objectives were to determine weed species shifts, concentration and distribution of weed seeds in the soil, and nutrient uptake by weeds.

Strict rules were presented to cooperating scientists, with little deviation allowed. To insure timely operations, during the growing season delays of more than two days were not tolerated. Meetings of all scientists were held during the winter, dealing initially with budgets, organization and procedures. At later meetings, operational problems and information dissemination were discussed. Of utmost importance was that the project was structured as a research-oriented interdisciplinary systems approach to solving a problem (as opposed to an educational or demonstration project). The study was designed as a long-term procedure to investigate the in-

Table 4. Criteria leading to the organizational and operational success of the USDA-ARS IPM project.

Organization	Operation
Invite cooperators early	Plot design and size
Visit on-going projects	Farm-size machinery
Objectives (three levels)	Combined tillages
Strict guidelines	Long term
Meetings	Scientific measurements
Interdisciplinary design	Timely management

fluence of each year's strategies and tactics on subsequent crops and pests.

A valuable decision made before the study began was for the project leader to visit large field-size IPM projects at Ft. Collins, Colorado and West Lafayette, Indiana. The objectives of these trips were to discuss problems, solutions, ideas, methods and strategies pertaining to organizing and conducting large interdisciplinary field research, and to observe field-scale operations. These visits reduced the number of unforeseen problems and answered many operational questions.

Operational structures

Specific field operations also contributed to the success of the project (Table 4). The experimental site encompassed 32 ha and was located on a single soil type close to the equipment at the research farm. Emphasis was on weeds, a major impediment to conservation tillage. Therefore weed management levels were assigned to subplots, which increased precision for weed management analysis. Individual plots were large enough (Young, F.L., et al., 1994) for long-term experiments (Frye and Thomas, 1991) and were divided lengthwise in half into a harvest side and a sampling side (Young, F.L., et al., 1994).

Probably the wisest decision was to plant all crops in both rotations every year. This eliminated much of the variability, with all crops affected equally by environmental variations and pest incidence. Farm-size machinery was used for most operations. This was more acceptable to growers and made the IPM methods and procedures credible for their farms. Rather than studying three different tillage systems, we combined reduced tillage and no-till into a conservation tillage system within each rotation. This system of planting winter wheat no-till and the two subsequent crops with reduced tillage was profitable. Also, it successfully controlled erosion and eliminated residue management problems after winter wheat.

A major strength of this project was that the research was conducted for a long enough time (two complete crop rotation cycles) to go beyond the transition period and allow the primary treatments to develop, stabilize and mature (Young, F.L., et al., 1994). Sometimes erroneous conclusions may be made because a study was conducted for only one rotation cycle (Goldstein, 1986) so that treatments had not matured. If our study had ended after one rotation cycle we would have reached the false conclusion that weeds and diseases are not a problem in monoculture wheat. Only near the end of the second rotation cycle did they become severe problems. We collected baseline data on several parameters in 1985 and measured them again at the end of the study, which allowed us to examine long-term changes. Because this project was research-oriented, all data and information were collected scientifically, which greatly reduced variability. The performance of each system was based on actual measurements, not assumptions from previous studies (Goldstein and Young, 1987) or estimates from county offices and farm managers (Reganold, 1987). The complexity and scope of the project greatly increased the management decisions and time required. The entire experimental area was scouted twice a week, which allowed problems to be recognized promptly and identified correctly.

This project has been recognized as a successful endeavor and is currently funded for an additional three years by USDA-ARS, Washington State University, and University of Idaho. Areas of increased research emphasis include reduced pesticide input, soil health, and insect pests and diseases of peas.

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Whole farm systems research: An integrated crop and livestock systems comparison study

John Luna, Vivien Allen, Joseph Fontenot, Lee Daniels, David Vaughan, Scott Hagood, Daniel Taylor, and Curtis Laub

Abstract. *To examine the long-term productivity, profitability, and ecological interactions associated with whole farming systems, we established an interdisciplinary replicated comparison of a conventional and an experimental alternative crop-livestock farming system in southwest Virginia in 1988. The conventional system uses the best management practices commonly used in the mid-Atlantic region. The alternative system puts more emphasis on crop rotation, grazing and forage management, conservation tillage, cover crops, and integrated pest management. Each is managed as a year-round system, with management decisions based on the system's overall goals.*

The comparison is planned to run for 10 years, so that only preliminary conclusions can be drawn so far. These include the following: 1) similar total productivity can be achieved with either reduced or full use of herbicides and insecticides; 2) the need for N fertilization can be decreased using grazing management and short-rotation alfalfa; and 3) recycling of manure from cattle fed corn silage provides most nutrients needed for the following corn crop. The comparative profitability of the two systems has fluctuated among years, and it is too early to know which system is more profitable. The process of interdisciplinary systems research has increased our knowledge of total system interactions, challenged prior assumptions, and clarified the methodological problems of integrated systems research.

Key words: crop-livestock systems, integrated farming systems, intensive grazing, conservation tillage

Background and Scope

In 1987 a seven-member interdisciplinary research team from six academic departments at Virginia Polytechnic Institute and State University (VPI&SU) worked with producers and Extension personnel to design an integrated farming systems project. Two fundamental questions were asked: 1) Can we redesign farming systems to maintain or improve farm profitability and soil productivity while reducing reliance on nonrenewable inputs and reducing undesirable environmental impacts? 2) Can we design and conduct systems-level experiments to answer these questions?

In 1988 a Farming Systems Comparison Study (FSCS) was initiated near Blacksburg, Virginia, to compare a conventional crop-livestock system typical of the mid-Atlantic region with an experimental alternative system to produce cattle of desirable slaughter weight and grade. The conventional system uses the best management practices currently recommended by Cooperative Extension and commonly used by growers in the region. The alternative system involves a different integration of farming practices, with emphasis on minimizing soil erosion and agricultural chemical inputs while maintaining or improving economic viability.

Each system has been established on four 4-ha plots with six steers each, for a total of 32 ha and 48 steers (Table 1). Although the land area and total animal stocking rate are the same, the two systems' crop mix, rotation plan, and production methods differ. Grazing is more intensive in the alternative system to reduce harvest costs, optimize forage utilization, and recycle animal manures.

The alternative system relies more on crop rotations and grazing to reduce insect pest damage than does the conventional system. In both systems, pest populations are sampled and economic thresholds are used to choose insecticide applications. Minimal use is made of preemergent herbicides in the alternative system, with postemergent herbicide applications based on the species, densities and growth stages of the weeds.

The FSCS is a focal point for an Integrated Farming Systems Project at VPI&SU (Fig. 1). This project also includes research and demonstration work on several cooperating farms in Virginia that deal with cover crops, conservation tillage, and integrated management of weeds and insect pests. Also associated with this project are several replicated research trials at Virginia experiment stations. Technologies and knowledge devel-

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Table 1. Land area and stocking rate for two crop and livestock systems for production of steers from weaning through slaughter.

Conventional System		Alternative System	
	Per replicate		
Pasture (ha)		Pasture (ha)	
Tall fescue	1.6	Fescue-alfalfa	1.6
Fescue-red clover	1.2		
Crops (ha)		Crops (ha)	
Corn for silage	0.6	Corn for silage	0.6
Alfalfa	0.6	Wheat/millet	0.6
		Alfalfa (first year)	0.6
		Alfalfa (second year)	0.6
Total, crops and pasture	4	Total, crops and pasture	4
Steers	6	Steers	6
	Total for the experiment		
Land (ha)	16	Land (ha)	16
Steers	24	Steers	24

oped in these associated projects are used to modify the practices used in the FSCS.

Systems Being Compared

In the conventional system, each replicate consists of 1.6 ha of N-fertilized tall fescue (*Festuca arundinacea*) for winter stockpiling, 1.2 ha of a mixture of fescue and red clover (*Trifolium pratense*) for grazing and hay, 0.6 ha of alfalfa (*Medicago sativa*), and 0.6 ha of corn (*Zea mays*). A winter cover crop of cereal rye (*Secale cereale*) is planted each year after corn harvest. The fescue and fescue-clover fields are maintained as permanent pastures. Alfalfa and corn for silage are grown in the same fields for 5 years, and then are rotated.

Weanling steers enter the conventional system approximately November 1 each year, grazing tall fescue that has been managed for fall and winter stockpiling. Fescue is fertilized with 80 kg N/ha in early August and is allowed to accumulate until grazing begins in November. Hay previously cut within the system is provided as a supplement if forage for grazing be-

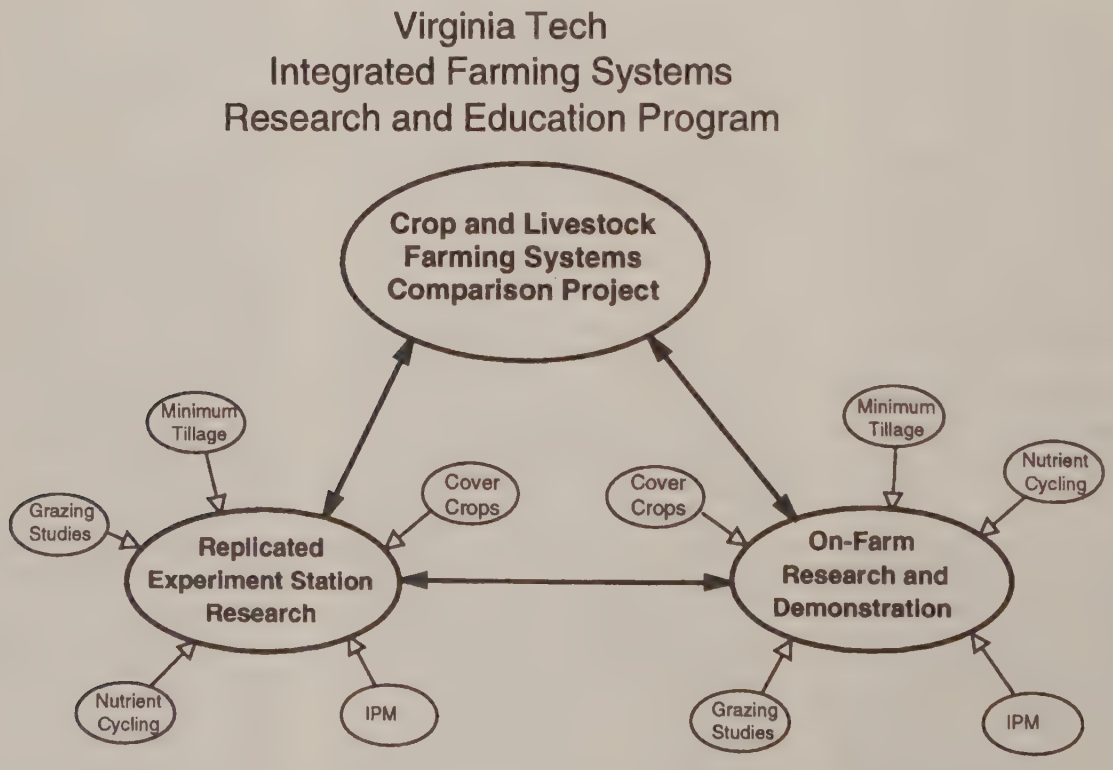

Figure 1. Relationship of the Crop and Livestock Farming Systems Comparison Project to other Experiment Station and on-farm research and demonstration projects.

comes limiting. Cattle remain on N-fertilized fescue into the spring and summer. Hay is harvested from spring growth of fescue-red clover. Regrowth of fescue-red clover may be grazed or cut again for hay, depending on the season. Pastures are managed so that by August 10, fescue has been grazed and cattle are moved to fescue-red clover, where they remain until they enter the feedlot in mid-October. Nitrogen is applied to the all-fescue pasture and stockpiling begins for the next group of cattle.

In the alternative system, each replicate consists of a 1.6-ha field of fescue-alfalfa mixture for stockpiling, grazing, or hay, and four 0.6-ha fields rotated among the following crops in a four-year rotation: corn, wheat (*Triticum aestivum*) double cropped with foxtail millet (*Setaria italica*), followed by two years of alfalfa. A cereal rye cover crop is no-till drilled into the second-year alfalfa before corn.

The alternative system uses tall fescue-alfalfa for continuous grazing by steers in autumn and winter. Fescue-alfalfa is not fertilized with nitrogen. By late February, the steers are fed hay or graze within the crop paddocks (or both). Spring growth of fescue-alfalfa is harvested for hay. Regrowth of fescue-alfalfa is grazed rotationally by dividing the pasture into eight paddocks. The steers graze fescue-alfalfa during summer until stockpiling begins by September 1. A more detailed description of the system is presented by Luna et al. (1991).

In October, the steers from both systems enter the feedlot for finishing on corn silage produced in their respective cropping systems. The steers in the conventional systems are given soybean meal supplement. Those in the alternative system receive poultry litter as a crude protein supplement to the corn silage diets. Manure produced during the finishing phase is collected separately for each system and is applied to the land the following spring to provide nutrients for the corn in the respective system. In the finishing feedlot, each replicate of six cattle was separately enclosed, fed, and weighed. Manure from the cattle in each system was collected and stored in a separate roofed facility to allow it to be returned to the land in that system.

Project Organization and Goals

When our group of research and extension workers began meeting in 1987 to form an interdisciplinary team to do this research, we had several motivations. One was the growing recognition that although controlled-factor, reductionist experimentation is a powerful and useful approach, it is inadequate to address larger questions relating to ecological interactions of whole farm systems and their long-term environmental and economic sustainability. Although we each had different experiences in farming systems research, we had a common interest in designing a model system that would incorporate our best thinking and serve as a learning laboratory to develop our knowledge. There was a strong interest in designing a crop and livestock production system that would optimize the use of on-farm, renewable resources to minimize the need for off-farm, non-renewable inputs.

This system would try to maximize beneficial ecological processes, such as nutrient cycling and biological control, while minimizing detrimental effects. Grazing and crop production would be integrated to optimize forage quality and availability, help prevent pest problems, and conserve or improve long-term soil quality and productivity. From our collective research experience, we believed such a system would be more environmentally sustainable and economically profitable than the "conventional" crop and livestock systems typical of the mid-Atlantic region.

From an agroecological perspective, we were interested in systems effects on weed and arthropod communities and physical, chemical, and biological changes in the soil. We also were interested in potentially unknown emergent properties of the systems that would appear over many years.

Besides their scientific interests and their research and education goals, the members also had a strong desire to work with an interdisciplinary team and be part of a larger group effort. We believed that interdisciplinary teamwork would reward us through greater collaborative learning. Although we realized that collective decision making would involve conflicts and disagreements, we felt the endeavor to be worth the effort.

Design Considerations

A fundamental problem with designing agricultural systems experiments is labeling the systems and then selecting practices that represent the labels. For this project, the labels "conventional" and "alternative" do not describe complete systems. There are no firm boundaries or guidelines that define either system. Rather, the systems represent different goals and varying sets of practices, with considerable overlap between them. Designating which practices (such as crop mix, rotations, and fertilizer and pesticide use) belong to each system is arbitrary. This task would have been easier if instead of the alternative system, we had chosen a certified organic system, which has lists of permitted and prohibited materials. But even within an organic system there are many choices of inputs and practices that make each farming system unique. In our study, any conclusions about "conventional" and "alternative" systems refer only to the particular systems that we compared.

A primary question was how to design, manage and integrate a cattle, pasture and crop production system that would address multiple goals. A long history of grazing and forage management research at VPI&SU (Blaser, 1986; Allen et al., 1989) had developed both a strong theoretical base and a body of practical knowledge. A major goal of this work was to use mixed swards of a grass such as fescue and a legume such as alfalfa to reduce the need for purchased N fertilizer. Since the integration of grazing was a focus of this project, a fundamental consideration was to design pasture and crop systems that would optimize year-round availability of forage. The experiment was designed to contain each herd within the boundaries of each system, thus retaining nutrients from the grazing animals' manure.

Because of the well-documented effects of crop rotation on crop yields, nutrient cycling, and the abundance of weeds, pathogens and insect pests (Bezdicek and

Granatstein, 1989; Francis and Clegg, 1990), a primary design consideration was to have a suitable crop rotation for the alternative system. The choice of a four-year rotation for the crop production blocks of the alternative system (Fig. 2) was based on several assumptions: residual N from alfalfa would be captured by the winter rye and corn crops; wheat could be managed as either a grain or forage crop, giving flexibility to the system; foxtail millet would be a summer crop and would suppress weeds for the following no-till planting of alfalfa; and planting corn each year following alfalfa would reduce the incidence of insect pests.

Alfalfa would be grown for two years and be followed by a winter rye cover crop to capture residual N. The corn planted for silage also would use residual N from the alfalfa, supplemented by manure stored in the feedlot operation. Corn would be grown for one year and be followed by winter wheat. The wheat could be used as a grazed forage in the winter or spring, depending on the need for forage, or could be allowed to mature to grain. Foxtail millet, a short-season hay crop, was no-till drilled after the wheat as a smother crop for weeds (Forney et al., 1985). Alfalfa was then no-till drilled into the millet stubble, completing the cycle.

A specific objective for using a crop rotation in the alternative system was to control western corn rootworm (WCR) (*Diabrotica virgifera virgifera* LeConte). Work in the Midwest has shown that WCR is monophagous on corn, so that breaking the cropping cycle with any other crop reduces or eliminates the need for broad spectrum soil insecticides (Levine and Oloumi-Sadeghi, 1991). Extended diapause has been observed in WCR populations in the Midwest, allowing some individuals to survive a single year rotation out of corn (Krysan et al., 1986). In the alternative system of the FSCS, however, corn would be grown only every fourth year on any given plot. Therefore, we believed we could eliminate soil insecticides for WCR control in this system.

Results

Because these systems have a complex array of crops, cattle grazing patterns, fertilization, pest management, and planting and harvesting dates, it is difficult to describe fully the project's design, procedures and results. Adding to this difficulty is the highly variable year-to-year weather, which significantly affects system performance, particularly since there is no irrigation. Because of this complexity, we are publishing more detailed methods and results in appropriate disciplinary journals; in this paper we discuss some broader problems and dilemmas associated with

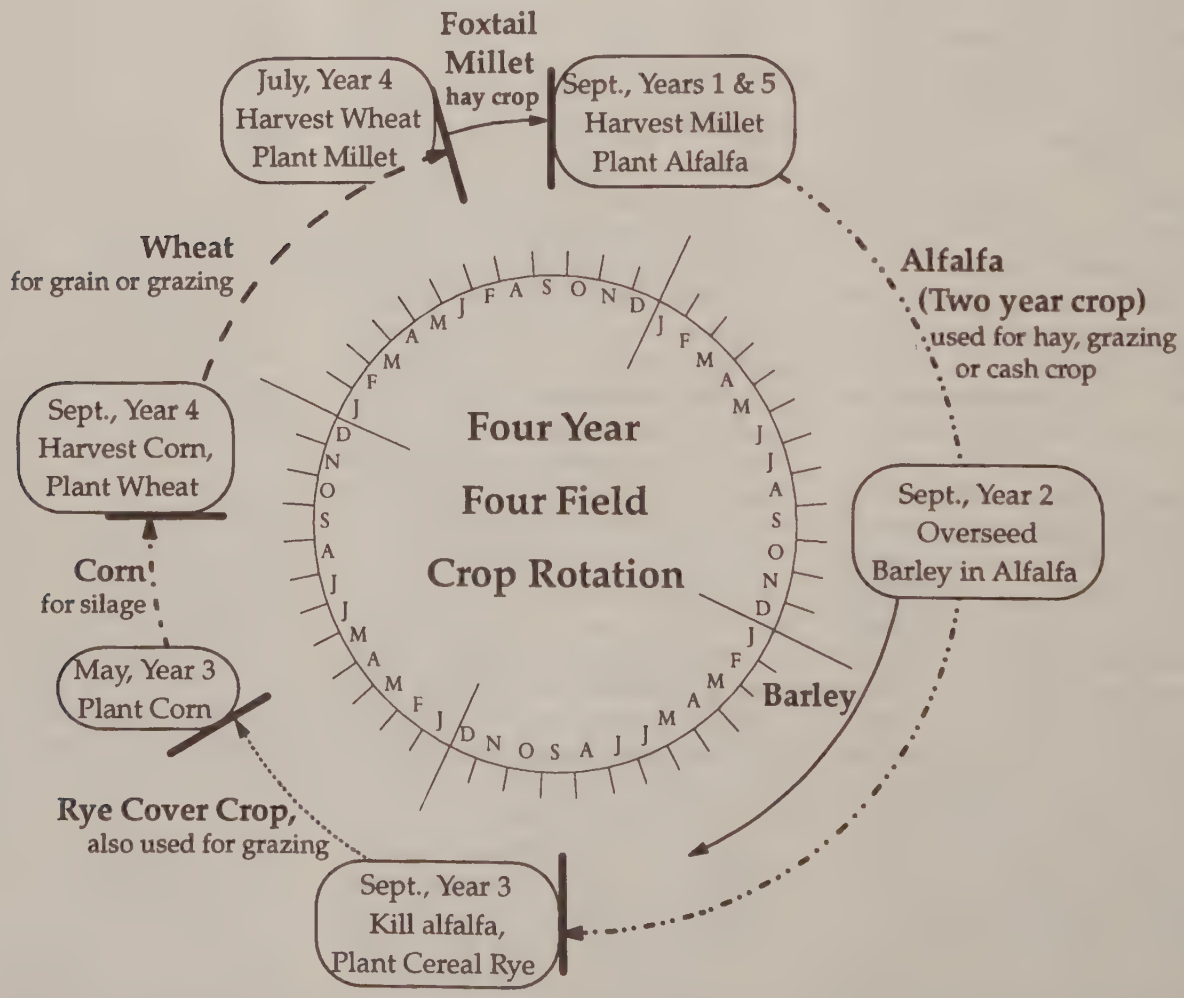

Figure 2. A four-year, four field crop rotation sequence used in the low-input crop and livestock system.

farming systems research. (The 1993 Project Report to the USDA-SARE program, "Sustainable Crop and Livestock Systems for the Southeastern United States," can be obtained by writing to Vivien Allen, VPI&SU.)

The FSCS is a long-term project: its first phase is completed following the five-year rotational cycle of the conventional system. Although five years of cropping have occurred, cattle have only been sold for two years, with the 1993 cattle not to be sold until spring of 1994. We can draw some tentative conclusions, however (Allen et al., 1993):

- Crop and livestock productivity were similar in the conventional and alternative systems, but less herbicide and insecticide were required in the alternative system.
- Grazing management and the use of alfalfa can decrease the need for N fertilization.
- Recycling the manure from cattle fed on corn silage provides most nutrients needed for the following corn crop.
- Including poultry litter in cattle diets increases the nutritive value of manure from the cattle.
- The comparative profitability of the two systems has varied among years, and it is too early to know which system is more profitable.

Changing Practices within Systems

From the beginning, the FSCS was envisioned as an evolving experimental laboratory that would change as we learned from our experiences. Although the cropping and grazing blocks and crop rotations were considered inviolable, the specific practices used to grow the crops could change. Although this strategy was set forth clearly in the planning stage, it was debated within the group as the project unfolded.

When the project began in 1988, several members had just begun work on innovative approaches for reducing herbicide inputs in conservation tillage for silage corn. This involved integrated ridge-till systems using mowed cover crops, banded herbicides and cultivation, and new approaches to no-till production using various methods of cover crop management. However, none of these approaches had been developed sufficiently at the time, and we had to take a "best guess" at which cover crop management, tillage, and weed control practices might work in the alternative system. Obviously, plowing and mechanical cultivation of weeds was one approach to reducing or eliminating herbicides in the alternative system. However, because of the rolling terrain of Southwest Virginia and the need to minimize soil erosion, we tried an alternative conservation tillage system.

This practice started in Fall 1989 with no-till drilling of cereal rye into second-year alfalfa. We then used the cattle to graze the cover crop periodically during the winter, and mowed the cover crop in the spring before planting corn. Mowing had been shown to be a promising method of killing rye cover crops (described in a later publication by Laub and Luna, 1991). We then planted no-till corn, banded atrazine and metolachlor in a 22-cm band over the row, and attempted to cultivate the row middles with a Buffalo® ridge-till cultivator.

This system performed poorly, for several reasons. A period of cool, rainy weather followed the mowing of the cover crop, allowing the rye to regrow. The banded herbicides failed to control many weeds within the row, and the ground was too compacted from cattle grazing and machinery traffic from the previous alfalfa harvests to allow good penetration by the cultivator. Overall, cover crop suppression and weed management were inadequate. Corn yield in the alternative system was about half that of the conventional system.

Because of these poor results, in 1991 we decided to try mowing with spring grazing until just before corn planting as another way to suppress the cover crop without herbicides. This method also failed to provide adequate weed control, and corn yield was significantly reduced in the alternative system. At the time, in replicated, on-farm research trials we were refining the use of a rye and hairy vetch cover crop that was killed by rolling it down with an offset disk. Corn was planted using a John Deere Model 71 no-till planter modified with sweeps to move the cover crop residue out of the row in front of the seeder (Vaughan et al., 1992). The first year results were promising for weed control, stand establishment and crop yield.

Thus, we were faced with a dilemma. Should we continue the original alternative corn production system in the FSCS, although it clearly was not working, or should we change to a more promising approach? One side of the question argued that you can't change "treatments" in the middle of an experiment. The opposing argument, which finally prevailed, was that one purpose of the FSCS was to incorporate our best knowledge, rather than trying to keep these systems constant merely for the sake of comparing them. If one practice clearly wasn't working but there was a more promising alternative, then the alternative should be used. We therefore decided to change corn production practices in the alternative system. We eliminated spring grazing of the cover crop, and instead killed it using a combination of glyphosate and rolling down with a sprocket roller. No other herbicides or cultivation were used in the corn crop. In 1992, corn silage yields were almost identical in the two systems, but the new approach greatly reduced herbicide use compared to the conventional system. This alternative is being further refined in several small-plot experiments next to the FSCS.

Cause and Effect in Farming Systems Experiments

The departure from traditional, controlled-factor, reductionist experimentation to holistic systems experimentation decreases our ability to determine cause and effect relationships. In a controlled-factor, replicated experiment, such as a factorial design involving three tillage practices and four N fertilizer rates, statistical analytical procedures can be used to test hypotheses about the effects of the tillage and fertilizer on various outcome variables. The investigators can make statements about the results of the experiment with calculated probabilities of error. This procedure has worked well for experiments involving just a few treatment variables.

But if this 3×4 factorial experiment (assuming four replicates) is expanded to include four methods of weed control and three different insecticides, for example,

the number of plots jumps from 48 to 576, making the experiment unmanageable and prohibitively expensive. For an experiment involving grazing livestock, in which 6 head of cattle and 4 ha of land are necessary for each replicate, controlled-factor experiments involving multiple treatment variables clearly are unreasonable.

In the FSCS described here, even with only two system treatments and four replications, the experiment requires 32 ha. Because each system of the experiment is replicated, statistical analysis can be conducted to compare certain sampled variables for each system. Examples include animal performance, such as rate of gain and total gain, total forage yields, and total economic cost and returns. Because the crops vary between the two systems, it is possible to compare crop yields and related variables only for corn, since this is the only crop planted and harvested at the same time each year in both systems. Alfalfa is grown in both systems, but differs in age of stand after the first two years of the rotational sequence. Also, harvesting and grazing patterns for alfalfa differ between the two systems because they depend on forage needs within each system.

In these statistical comparisons of the two systems, cause and effect relationships cannot be deduced easily. The measured response is the combined result of many factors in each system, operating not just during a single year, but over time. This makes interpretation of experimental results difficult, given the complexity of the project, the multiyear effects of specific management and cropping practices, and the changing production practices in each system. However, because this project took a multifaceted approach involving "satellite" reductionist research, both on the experiment station and on-farm, many specific questions that arise in the Farming Systems Comparison Study can be broken out into more controlled experiments, resulting in an iterative learning process.

Educational Audience

The Integrated Farming Systems Project was designed with both research and educational goals. The on-farm research components were established to foster exchange of information at the farm level and to evaluate alternative practices under varying soil, climatic and managerial conditions. The FSCS also was established to serve as a teaching laboratory for farmers, agricultural professionals, and university students. Because it is unique in integrating crops and livestock, it also serves a national and international research community interested in whole farm systems research.

Knowledge gained from this project is distributed through a multifaceted education program. Several field days and farm tours have been conducted at the Farming Systems Comparison Study site for farmers, extension agents, agribusiness representatives, visiting foreign agricultural tour groups, and university classes. Results have been presented at more than 30 winter educational meetings for farmers.

Another goal of this project is graduate student education. To date, eleven graduate students have had much of their graduate thesis work associated with this project. These students have made several presentations at grower and scientific meetings, and coauthored several refereed publications.

Conclusions

Interdisciplinary research comparing farming systems clearly requires significantly greater time from the participating scientists if they are to participate in decision making and if they are to consider that they "own" the project. Because of the complexity of the project, its methods and results are more difficult to communicate. Also, the results require more interpretation than those of component-level experiments. However, some questions can be addressed only through long-term, whole farm system approaches.

A continuing research and demonstration project also serves a valuable educational role, since it can be visited year-round by local, state and international groups. The system-level focus of the project has forced the project participants and visitors to the farm to think more holistically. The project also has generated many research questions for graduate student theses and dissertations that have contributed to a greater understanding of the systems' components. The project clearly will become more valuable over time as more effective practices are introduced into the systems and as we learn their longer-term economic performance and agroecological impacts.

Acknowledgments. We appreciate the funding for this project provided by the Southern Region USDA Sustainable Agriculture Research and Education Program, the John Lee Pratt Animal Nutrition Program, and the VPI&SU College of Agriculture and Life Sciences. We thank Dwight Paulette, Charles Shorter, George White, Jim McDaniels, and other members of the VPI&SU farm production team for invaluable assistance in construction, fencing, crop production and cattle handling and feeding. We also thank all the graduate students who have helped with data collection and crop and animal production.

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INSTITUTE NEWS

Wallace Institute Board Elects New Officers, Installs New Members

The Wallace Institute Board of Directors has elected new officers for the coming year, and installed five new members. The new President is Michael Heller, Director of The Clagett Farm in Upper Marlboro, Maryland, a 285-acre research and demonstration farm operated by the Chesapeake Bay Foundation to educate farmers and the public on environmentally sound farming methods. The new Vice President is Dr. David F. Bezdicek, Professor of Soils at Washington State University; Secretary is Dr. William C. Liebhardt, who directs the Sustainable Agriculture Program at the University of California-Davis; and Treasurer is Dr. Anne K. Vidaver, Chairperson of the Department of Plant Pathology, University of Nebraska-Lincoln.

The new members of the Board are: **Dr. Cornelia Butler Flora**, Professor and Head, Department of Sociology, Virginia Polytechnic and State University; **Dr. James William Gibbons**, owner of a family-run small fruit and vegetable farm in Ozark, Arkansas, and former Senior Rice Scientist, Centro International de Agricultura Tropical (CIAT), Colombia, South America; **Dr. Esther Nickel** of the Religious Sisters of Mercy, Jackson, MN, Ph.D. in agronomy, and manager of a student learning center for practical farm experience; **Kenneth J. Taylor**, Executive Director of Minnesota Food Association, and former Chair, North Central Region Administrative Council, USDA SARE Program; and **Gregory C. Watson**, Eastern Regional Director, The Nature Conservancy, Boston, Massachusetts, and former Commissioner, Massachusetts Department of Food and Agriculture.

Tracy Irwin Hewitt Joins Wallace Institute as Policy Analyst

Tracy Irwin Hewitt, a former analyst with the Sustainable Production Systems Section of the USDA's Economic Research Service, has joined the Wallace Institute as a policy analyst. During her first year at the Institute, she will spend half her time serving as the Washington, D.C.-area representative of the Council for Food, Agricultural, and Resource Economics (C-FARE), a non-profit professional organization. For both C-FARE and the Wallace Institute, she will follow and report on legislative and administrative policy affecting agricultural research and education.

Among Ms. Hewitt's initial projects with the Institute's Policy Studies Program will be the synthesis of information advancing the case for sustainable agriculture as an approach to feeding the world's growing population. She received her B.A. in economics and an M.S. in agricultural and resource economics from Michigan State University. While a graduate student at MSU, she was a research assistant with the Department of Crop and Soil Sciences and was part of a farmer-led, interdisciplinary team researching sustainable farming in Michigan.

Organic Farmers, in First Survey, Name Top Three Research Priorities

The first national survey of certified organic farmers ever conducted has found that the top three research priorities identified by the growers are to increase consumer demand for organic products, study the relationship of growing practices to crop quality and nutrition, and study the relationship between plant nutrition and pest resistance.

The survey, conducted by the Organic Farming Research Foundation was mailed to 2,700 certified organic farmers; 550 farmers responded. Nearly one-third of the farmers surveyed have participated in on-farm organic farming research projects; more than 80% said they would be interested in participating in on-farm organic research projects if the resources were available.

More than 60% of the farmers surveyed grow vegetables; livestock are most frequently used as a fertilizer source for use on the farm, according to the survey. More than 80% of those responding are sole proprietors of their farms or co-owners of their farms in a family partnership. For more information, contact OFRF, P.O. Box 440, Santa Cruz, CA 95061; (408)426-6606.

An interdisciplinary, experiment station-based participatory comparison of alternative crop management systems for California's Sacramento Valley

Steven R. Temple, Diana B. Friedman, Oscar Somasco, Howard Ferris, Kate Scow, and Karen Klonsky

Abstract. *In 1989, a group of researchers, farmers and farm advisors initiated an interdisciplinary study of the transition from conventional to low-input and organic management of a 4-year, five-crop rotation. Crop yields initially varied among systems, but now appear to be approaching each other after a transition period that included the development of practices and equipment most appropriate for each system. Farming practices and crop production costs are carefully documented to compare the various systems' economic performance and biological risks. Supplying adequate N and managing weeds were challenges for the low-input and organic systems during the first rotation cycle, and experiments are being conducted on an 8-acre companion block to find solutions to these and other problems. Leading conventional and organic growers provide a much-needed farmer perspective on cropping practices and economic interpretations, because we try to provide "best farmer" management of each system. Research groups within the project are focusing on soil microbiology, economics, pest management, agronomy and cover crop management.*

Key words: farming systems, crop rotation, participatory research, organic farming, sustainable agriculture, soil ecology

Introduction

Public concern about pesticide residues in food, environmental quality, groundwater contamination, dependence on finite supplies of fossil fuels, and soil and water conservation have led many growers and researchers to consider alternative means of agricultural production. New research in this area is generally labeled "sustainable agriculture." Practices commonly associated with sustainable management include reduced use of chemicals and fossil fuels, maximum use of on-farm inputs, crop nutrient recycling, and increased use of diversified crop rotations that enhance soil cover and fertility.

MacRae et al. (1990) outlined three approaches for moving agricultural systems toward sustainability: increased efficiency of input use, substitution of inputs, and redesigned systems. Increased efficiency might involve banding herbicides or side-dressing corn with N, for example. Substitution methods include replacing inorganic fertilizer by cover crops or manure, or replacing pesticides by biological control. Redesigning a system, which is much more complex, involves restructuring the farming operation so that it mimics natural ecosystems by cycling nutrients, mixing species (polycropping), conserving organic matter, and providing habitat for natural enemies.

Much early work among university researchers focused on substitution rather than systems redesign and did not take into account the many integrative factors that comprise a sustainable system. Therefore, much of this research was unable to show that sustainable agriculture was an acceptable approach (Janke et al., 1991). As the concepts and practices of sustainable agriculture have become more widespread, research in the U.S. has shifted toward experiments that include systems redesign. These experiments include farming systems research at experiment stations (House et al., 1984; Granatstein et al., 1987; Liebhardt et al., 1989; Luna et al., 1991; Peters et al., 1992), where it is possible to control the management and timing of operations. Much systems research also is being conducted on working farms where comparisons may be confounded by soil, climatic, and management differences but where real world constraints are integral components of the project (Lockeretz et al., 1981; Reganold et al., 1987; Reganold, 1988; Dobbs et al., 1991; Shennan et al., 1991).

Although farming systems experiments increasingly address system redesign, the

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question of how farming systems are best studied has received less attention. Since sustainable farming systems are complex and specific to the location, understanding the principles and processes that characterize such systems is most readily achieved by a multidisciplinary project.

In 1988, a group of farmers and University of California researchers met at U.C. Davis to plan the Sustainable Agriculture Farming Systems Project, a large, interdisciplinary project whose primary objective was to compare conventional, low-input, and organic farming systems using a management style we call "best farmer practices". The study attempts to combine the best features of both on-farm and experiment station research; it is established under controlled conditions on a research farm, yet employs commercial farming practices that must be economically justifiable and that are regularly evaluated by farmer cooperators. The project also is unusual in that four farmers (two organic and two conventional) and two Yolo County farm advisers participate in all decisions. Ten disciplines currently are represented: agronomy, agricultural economics, entomology, water science, nematology, plant pathology, soil microbiology, soil fertility, crop nutrition and weed science. Besides contributing disciplinary experience, each participant expects to learn from agricultural practitioners and find new, interdisciplinary applications for their science.

The study has three objectives:

1. To compare four farming systems that differ in their reliance on nonrenewable resources. This comparison will run for 12 years, encompassing three 4-year rotation cycles, and will document the following: growth, yield and quality of crops as influenced by management practices and rotations; abundance and diversity of weed, pathogen, arthropod and nematode populations and their effects on crop growth, yield and quality; changes in the biological, physical, and chemical properties of the soil and its water relations, and the effects of these changes on soil quality and crop productivity; and the cost of inputs, value of products, economic risk, and energy budgets.
2. To evaluate existing and novel low-input and organic farming systems, with emphasis on innovations that correct deficiencies, enhance profitability or reduce risk.
3. To distribute, demonstrate and facilitate adoption of information generated by this project.

This paper describes the design and function of the project and summarizes yield results from the first 4-year rotation cycle. More detailed descriptions of methods and data from studies of soils, pest management, and economics will be reported in a forthcoming volume of *California Agriculture*.

Experimental Design

The 20-A main experiment compares conventional, low-input, and organic management of a 4-year, five-crop rotation consisting of processing tomatoes (*Lycopersicon esculentum*), safflower (*Carthamus tinctorius)*, field corn (*Zea mays*), and either a small grain, a winter legume, or both, double cropped with dry beans (*Phaseolus vulgaris*) (Table 1). This rotation includes most of the annual row crops

Table 1. Crops grown for each rotation entry point in four farming systems.

System	Rotation	1989	1990	1991	1992
CONV 4[1]	1	tomato	safflower	corn	wheat/bean
CONV 4	2	wheat	tomato	safflower	corn
CONV 4	3	corn	wheat/bean	tomato	safflower
CONV 4	4	safflower	corn	wheat/bean	tomato
CONV 2	1	tomato	wheat	tomato	wheat
CONV 2	2	wheat	tomato	wheat	tomato
LOW	1	tomato	vetch/safflower	vetch/corn	oat-vetch/bean
LOW	2	lupin	vetch/tomato	vetch/safflower	vetch/corn
LOW	3	corn	lupin[2]/bean	vetch/tomato	safflower[2]/bean
LOW	4	safflower	vetch/corn	oat-vetch/bean	vetch/tomato
ORG	1	tomato	vetch/safflower	vetch/corn	oat-vetch/bean
ORG	2	lupin[2]/barley	vetch[3]/tomato	vetch/safflower	vetch/corn
ORG	3	corn	lupin[2]/bean	vetch/tomato	safflower[2]/bean
ORG	4	safflower	vetch/corn	oat-vetch/bean	vetch/tomato

[1] Conventional 4-year and Conventional 2-year.
[2] Because of a combination of poor crop stand and slow development (compared with weed competitors), the crop and weed biomass were disked as a green manure.
[3] Vetch cover crop was disked and replanted late, which resulted in a poor production of biomass.

available to a grower in transition to low-input and organic practices; these crops are being grown by the project's certified organic cooperators. Because there are no adequate methods for managing weeds and providing adequate N fertility in organic and low-input wheat (*Triticum aestivum)* production, a mixture of oats (*Avena sativa)* and lana vetch (*Vicia dasycarpa*) was substituted for wheat in those two systems following corn and before double-cropped dry beans. A fourth management system is the conventional 2-year rotation of wheat and tomato used by growers and farm managers who wish to maximize short-term profits. Besides the five cash crops, the low-input and organic systems use N-fixing legume cover crops during the winter and spring preceding tomato, safflower and corn.

The experiment was designed to run for three cycles of the crop rotation, after which future directions will be determined. Crop production was begun late in 1988 on 0.3-A plots replicated four times for each crop and entry point of the rotation, for a total of 56 plots. Conventional (CONV-2 and CONV-4) management reflects the practices currently used by most row crop farmers in the Sacramento/Woodland area; organic (ORG) management is defined by California Certified Organic Farmer regulations; and low-input (LOW) management seeks to reduce dependence on inorganic fertilizers, pesticides, supplemental water, and fossil fuel (tillage). Because conventional "best farmer" practices often include IPM scouting and soil moisture monitoring, low-input management criteria have been the most difficult to define and apply consistently.

Systems Management

Each system is managed using "best farmer" practices recommended by the farmers and farm advisers who are members of the project, rather than by a prescribed set of guidelines. Best farmer management of each system requires appropriate equipment and timely management decisions that are responsive to weather and the biotic challenges of farming. We emphasize the effects of crops and weeds on subsequent crops, competing demands on management and equipment, economics of the whole farm, and long-term changes in the system, especially in soils.

Project leadership is shared by investigators who have no formal sustainable agriculture assignments but contribute time and resources to the multidisciplinary project to strengthen their individual teaching, research, and extension activities. Most important farm planning decisions are made by consensus, with special weight given to the recommendations of grower participants. The dynamics of our interdisciplinary and participatory process are vital to project success; the growers do not always have the same opinion, but as a group their perspective often differs from that of the researchers. Growers contribute actively to designing, executing, and interpreting all disciplinary aspects of the project.

Sampling and Pest Monitoring

We have taken extensive soil and plant samples throughout the project to make appropriate recommendations for crop nutrition and to document possible changes in soil physical and chemical properties, microbial activity, nematode and pathogen populations, and levels of toxic chemicals. Soil samples for nutrient analyses (20 to 30 random cores per plot) are taken at depths of 0-6" and 6-12". NO_3^- and NH_4^+ analyses were done by 2M KCl extractions and the diffusion-conductivity (Carlson) method on air-dried samples. We monitor crop development by recording stand establishment, plant growth, yield and quality. Because processing tomatoes are the key cash crop of the rotation, tomato growth parameters and petiole nutrient concentration are monitored throughout the season. Recommended IPM scouting procedures are used to monitor insects and diseases to allow timely crop management decisions and to explain losses in yield and quality. We sample and sort weeds by species at harvest and estimate fractional cover visually throughout the summer growing season.

We measure crop yield with both hand and machine harvesting. Machine harvesting is done with commercial-size equipment on the center one-third of each plot, and hand harvesting is done in a measured area next to the machine-harvested strip. We report machine harvested yields for all crops except where machinery was unavailable or was not performing at a commercially acceptable standard.

Detailed accounts of all farming practices are maintained for every crop in each farming system to estimate production costs accurately, which lets us simulate the system's economic performance on a 2,000-A farm. We discuss the costs and benefits of specific cultural practices with growers at meetings held every two weeks.

Results from the First Rotation Cycle

Yields from the first 4-year rotation cycle are presented in Table 2. Average yields for most conventionally grown crops are close to the Yolo County average. The analysis that follows highlights some apparent reasons for yield differences observed during the first 4-year rotation.

Tomato

Tomato yield is a critical concern because of the key economic role the crop plays in whole farm sustainability. Therefore, the significantly lower yield of low-input tomatoes in 1991 and of organic tomatoes in 1989, 1990 and 1991 may make these systems economically unacceptable during the transition phase. In 1989, vegetative growth was reduced in the low-input and organic tomatoes and fruit damage by insects was higher. The 1990 organic tomatoes yielded 20% less than low-input and conventional tomatoes. Soil sampling and plant growth analyses suggested that the reduction was caused largely by inadequate N supply from the vetch cover crop that preceded tomatoes in the rotation. Higher populations of pigweed (*Amaranthus* spp.), a preferred host of the armyworm (*Spodoptera exigua*), apparently aggravated the pest problems in organic tomatoes.

The conventional tomato yield of 45.6 ton/A in the 4-yr rotation in 1991 was 50% higher than the Yolo County average and significantly higher than the low-input and organic yields (34.9 and 28.2 ton/A, respectively). We attribute these advantages to differences in plant nutrition, as shown

Table 2. Crop yields for four farming systems during the first rotation cycle (1989-1992).

Year	Farming System				Yolo Co. average
	Organic	Low-input	Conv 4-yr	Conv 2-yr	
	Tomato (ton/A)				
1989	24.50b[2]	30.92a	34.33a	34.2a	30.2
1990	30.70c	36.28b	36.82ab	39.6a	28.8
1991	28.20c	34.85b	45.58a	37.4b	30.5
1992	42.66 [3]	42.87	47.70	41.3	33.8
	Safflower (lb/A)				
1989	1358b	1343b	2058a	—	2320
1990	2070	2350	2160	—	2100
1991	1990	1879	2155	—	1740
1992[4]	—	—	2575	—	1920
	Corn (lb/A)				
1989[5]	8360	10420	10160	—	9020
1990	10400	10000	9820	—	9640
1991	8140b	8180b	10120a	—	9180
1992	9840b	11840a	9520b	—	9800
	Wheat (lb/A)[6]				
1989	—	—	4507b	4916a	5200
1990	—	—	4615	4961	4660
1991	—	—	5273	5485	5380
1992	—	—	4694	4498	4440
	Beans (lb/A)[7]				
1990	Y 2218a	Y 2330a	S 1934b	—	1980
1991	RK 1592	RK 1457	RK 1140	—	1780
1992	Y 2830	Y 2716	Y 2442	—	1780

[1] All yields are with machine harvesting unless otherwise indicated.
[2] Differences between means followed by the same letter within a row are not statistically significant at the 5% level.
[3] Organic tomato yields were adjusted based on hand harvest data because of large harvesting losses during calibration of the harvester.
[4] Organic and low-input safflower were plowed under in 1992 and pink beans were planted, yielding 2,193 and 2,273 lb/A, respectively.
[5] No harvesting equipment was available in 1989, so hand harvested yields are reported.
[6] All wheat yields are with hand harvesting, except 1992 yields are with machine harvesting.
[7] All bean yields are with hand harvesting. Bean varieties: Y = Yolano Pink; S = Sutter pink; RK = Red kidney

by petiole NO_3^- levels during growth and early fruiting, and to a greater abundance of weeds competing for limited nutrients in the low-input and organic treatments (Table 3). After the 1991 tomato harvest, we decided to use transplants in the low-input and organic tomatoes in 1992 to allow better weed control and greater N fixation and biomass production by letting the preceding vetch cover crop grow longer. Also, N fertility in the organic treatment was enhanced by adding 2 ton/A of composted chicken manure (2% N) at transplanting and two foliar applications of fish emulsion and seaweed kelp fertilizers during crop growth. The low-input treatment received 9.6 lb/A of N as a starter at transplanting and 30 lb/A of N as NH_4NO_3 sidedressed. The 2- and 4-year conventional treatments received 6 and 9 lb/A of starter N respectively, and both were sidedressed with 120 lb/A of N.

There were no significant differences in tomato yields among systems for the 1992 harvest. As in previous years, the conventional yields were well above the county average. Therefore, the absence of significant differences was due almost entirely to increases in the low-input and organic yields.

Corn

Corn yield was less variable than tomato yield among treatments and years. Significant yield differences occurred only in 1991 (higher conventional) and 1992 (higher low-input). This is inconsistent with results from other studies that have shown that corn is not a good crop to use during transition because it has a high N requirement and is vulnerable to reduced yields from weed competition (Sahs, 1986; Janke et al., 1991). These factors appear to have caused the decline in corn yields in 1991, when the 3,000 lb/A vetch cover crops in the organic and low-input systems were inadequately incorporated (Table 4).

In 1992, adequate N was available in all three systems, but weed pressure contributed to a yield decrease in the organic system (Table 5). For the cover crop to be incorporated and the following corn crop to be planted at the best time, the weather must be clear and machinery must be available to do field operations that allow establishment of the corn crop without supplemental moisture. In 1992, irrigation was

Table 3. Crop yield, petiole NO_3^- and weed biomass for tomatoes in four farming systems for the 1991 and 1992 crop seasons.

Farming System	Petiole NO_3^- (ppm at early bloom)		Weed biomass (lb/A at harvest, dry weight)		Yield (ton/A)	
	1991	1992	1991	1992	1991	1992
Organic	1530b	6560b	46	162a	28.2c	42.7
Low-input	1800b	12220a	40	212a	34.9b	42.9
Conv. 4-yr	4270a	15470a	0	16b	45.6a	47.8
Conv. 2-yr	4100a	15150a	0	44b	37.4b	41.3

[1]Differences between means followed by the same letter within a column are not statistically significant at the 5% level.

needed to establish the corn in the organic and low-input systems, which led to heavy weed pressure. Weeds were managed with a contact herbicide in the low-input system, but this was not permitted in the organic system. Weed pressure in the organic system continues to be a problem, because inorganic herbicides are not allowed.

The decreased corn yield in the conventional system may have been caused by the use of double rows on 60-in beds, rather than the 30-in beds used in the low-input and organic systems. Grower participants suggested that with 60-in beds, different amounts of moisture are available to the corn roots that are oriented toward the furrow and toward the inside of the beds, respectively.

Other crops

Yields of safflower and dry beans have differed only slightly among systems. In 1989, safflower yield was significantly higher in the conventional than in the low-input and organic systems (Table 2). In 1990, yields of low-input and organic beans were significantly higher than the conventional bean yield. Beans also performed very well in 1992 as a replacement for a lost safflower crop. Obtaining a good stand of safflower following an N-fixing cover crop presents substantial challenges. Wheat yields in the 2-year and 4-year conventional systems were near the county average.

Several crops have been grown in the organic and low-input systems opposite winter wheat in the conventional systems, but we still do not have a reliable cash grain alternative to wheat. Four successive years of inadequate fall moisture and limited experience with stand establishment and harvesting equipment have led to inconsistent results with sweet white lupin (*Lupinus albus*) and oats/vetch seed crops. The challenges of managing winter cover and grain legume crops without herbicides or with short-lived, postemergent herbicides are partially offset by the option of planting or replanting crops of opportunity, such as spring barley (*Hordeum vulgare*) after lupin, and pink beans (*Phaseolus vulgaris*) after safflower.

Table 4. Yield (lb/A) of cover crop dry matter of Lana woollypod vetch planted in two farming systems for 1991 and 1992.

Crop	Organic		Low-input	
	1991	1992	1991	1992
Vetch/tomato	3913	3209[1]	3582	3392[1]
Vetch/corn	3846	4644	2877	4503
Vetch/safflower	3277	—	2448	—
Oat-vetch seed[2]				
Oat	819	402	1630	—
Vetch	964	257	463	—

[1] 1992 dry matter values include biomass contributions of vetch, volunteer oats, and weeds at time of plowdown.

[2] Values are for seed yield (lb/A) in the rotation position following corn and before double-cropped dry beans.

Whole Farm (Rotation) Results

Differences among the systems' management practices complicate the comparison of fertility and pest results for all crop-system combinations. However, the de-

Table 5. Corn leaf tissue N, weed biomass and yield, 1992.

Farming System	Leaf tissue N at silking (%)	Weed biomass at harvest (lb/A)	Yield (lb/A)
Organic	2.4b[1]	744a	9840b
Low-input	2.8a	33b	11840a
Conventional	2.8a	20b	9520b

[1]Differences between means followed by the same letter within a column are not significantly different at the 5% level.

velopment and use of innovative agricultural equipment to manage cover crops and control weeds without chemicals is the kind of adjustment that farmers say is required in the transition to low-input or organic systems. The farming systems group gave heavy weight to economic criteria in evaluating the crops and production practices used during the first 4-year cycle. Prices received, especially the premiums received for certified organic commodities, exert a powerful influence.

The rotation of processing tomatoes, safflower, field corn, and wheat or a winter legume followed by double-cropped dry beans is a good system for comparing crop performance and yields. The management of N-fixing cover crops as a green manure or seed crop has generated new opportunities and new challenges that require "best farmer" management and flexibility to work within constraints of time and weather. The late winter/early spring management of cover crops has become a central research theme in the large companion plots next to the main experiment. These studies deal with residue management, seedbed preparation, supplemental manuring, and the retention of sufficient soil moisture for germination of tomato, corn and safflower with little or no herbicide.

Insects, diseases, and plant parasitic nematodes have hardly affected productivity, in part because corn, safflower, beans, and wheat do not require intensive pesticide use. Similarly, early processing tomatoes receive a good price and have less severe pest problems than late-planted tomatoes. Weed management, on the other hand, has been a problem in almost all crops in the low-input and organic systems.

The interdisciplinary group is focusing on several key issues as the second rotation cycle begins. Besides identifying the best cover crops for each system/year combination, we are more intensively monitoring several phenomena that affect soil fertility and plant nutrition, particularly the timing of the availability of N from the cover crop and its relation to crop growth and yield. Other critical issues are the long-term implications of weed control and the related demand for creative management and appropriate equipment. Some cultural practices in the low-input and organic systems must be done within a narrow time interval, which results in a constant race with the weather. We also are seeking scale-neutral management systems that can be used by large and small growers alike.

Evidence is available on the pros and cons of different rotation entry points in each system, but the choice will depend on individual growers' economic situation and the wide range of costs and returns for the five cash crops in the rotation. Organically grown tomatoes receive an attractive price, but current organic regulations require a minimum of three years without pesticides before certification. This suggests that field corn would be the best entry point for the organic system, because it would allow certified organic tomatoes to be sold by the third year. However, growers must consider the implications of this choice for pest control, especially weed management. Of greatest concern are the entry point and short-term economic viability of the low-input system, which has no price premiums to offset potential cost increases in managing weeds and maintaining adequate fertility for high yields.

Companion Area Studies for Systems Experiments

An advantage of a large, multifaceted whole-system experiment is that it provides results about the interactions that make the whole system succeed. Such experiments also may represent true farming systems better. A major drawback, however, is the difficulty in understanding specific causal relationships because of the variability introduced by different farming practices. The Sustainable Agriculture Farming Systems Project has addressed this challenge by initiating research on important information gaps on an 8-A area next to the main experiment. Annually, 1.2 A is planted to each of the four summer cash crops of the rotation and managed at the low-input level. This provides a representative setting for experiments with materials, equipment, and practices that would disrupt the main experiment.

Our current research priorities are to identify a more suitable cover crop to follow tomato and precede safflower, and a cash crop to replace oats/vetch in the low-input and organic systems. Following tomato in the companion area, five species or species mixes (Lana vetch, purple vetch, cowpea/Lana vetch, fava bean/Lana vetch, and sorghum/sudangrass) are being tested for biomass, total N production and assimilation, and weed competition. This seasonal niche is particularly difficult to fill because tomatoes generally are harvested too early for vetch and too late for cowpeas to be planted. Safflower is planted in early spring, reducing the time available for spring growth of a fall-planted cover crop. High residual soil N following tomatoes makes immediate planting of a cover crop attractive for efficient nutrient cycling in the low-input and organic systems.

Berseem clover, lupin, chickpea, bellbean/winter pea, barley/vetch, and an oats/vetch control are being tested in 1993-94 after corn and before beans in the companion plot (double cropped dry beans will be planted in June). The agronomic suitability of organic soft white spring wheat also will be tested in 1994, with various seeding rates and fertility levels (composted manure). The group will then decide if any of these options merits further testing.

Information Dissemination

Results from the project are circulated by various means to interested growers, researchers, educators, pest managers, extension personnel, and the public. The most typical way is field visits and tours. Individuals and groups tour the project at least once per week. The experimental site also has brochures with a map and brief project history to encourage self-guided tours. Guided tours are provided by the research and production managers and by principal investigators or project cooperators.

Experimental plots of the project are a "living laboratory" and have become a model for teaching and instruction. During the first five years, six faculty members from Spain, Brazil, Italy, and Israel have spent sabbatical leaves with the project, contributing expertise and labor and gaining experience. Many graduate students have conducted M.S. and Ph.D. work on the plots. The experiment is routinely visited as a teaching/demonstration laboratory for U.C. Davis courses. Several of the principal investigators have been mentors to students from a U.C. Davis outreach program to provide research and career experiences to minority high school students.

The annual field day provides the most direct and immediate outreach to the public, researchers and growers. The 1993 field day, which offered lectures, plot tours, and demonstrations of soil biology and equipment, was attended by 150 participants from all over California. Special field days also are organized for specific topics, such as demonstration of novel equipment for incorporating cover crops.

Faculty members and researchers associated with the project also have conducted off-station seminars for growers in the Woodland and Stockton areas and have participated in conferences organized by professional societies, private companies, and academic institutions. One faculty member used this project as a model in a two-week workshop on sustainable agriculture in Argentina in September 1993.

Information also is disseminated through more traditional channels, such as reports transmitted to all county offices in California through newsletters of the U.C. Sustainable Agriculture Research and Education Program. The extension specialists and cooperating farm advisers on the project each typically give 25 or more presentations per year to growers, advisers and commodity groups. Relevant information also is published in newsletters prepared by the project's farm advisers. Many county-based farm advisers are repeat visitors at annual field days, where they provide opinions and advice. Data from the first four years are currently being summarized in manuscripts for publication in disciplinary journals by each investigator.

Conclusions and Implications

The many farmers, farm advisers, researchers, and students who meet every two weeks on this participatory project have invested substantial time to make "interdisciplinary" a meaningful part of our vocabulary. With farmers contributing to research and with researchers seeking to understand farming better, our farmer participants not only provide a reality check for the interventions and interpretations the researchers suggest, but also are role models for integrative and interdisciplinary education. Researchers have learned from growers some excellent educational tools for improving communication at county meetings and have gained a valuable insight about how growers perceive the transition "learning curve."

The agribusiness sector has become more interested and less skeptical as the project has evolved, in part because of the active way that growers and farm advisers have contributed to the research and educational process and the willingness of researchers to become students. Several agribusinesses contribute nominal support to the project, and their professionals are well represented at our annual field days and county meetings.

After the first rotation cycle, several trends are apparent, although more years are needed to reach definitive conclusions. Two key aspects of a successful transition are maintaining N fertility by skillful cover cropping and supplemental use of manures and other products, and adequate weed management. These challenges have multiple dimensions, and both interact with other aspects of the rotation. For example, sustainable N management will require skillful manipulation of legume and non-legume cover crops, and timely and precise soil and residue management. Sustainable weed management also requires precise manipulation of moisture, fertility, and solar energy in ways that favor the crop over the weeds. Both objectives also require major attention to the weather, something that agriculturists have labored for decades to minimize the effects of in our farming practices.

Many of the results to date involve principles and processes of soil ecology, and more of our group's effort is being directed accordingly. It is too early to predict whether our results will contribute more to increased efficiency, input substitutions, or redesigned systems. Each probably will be appropriate, and their successes and failures no doubt will be observed in the soil.

Our preliminary results suggest that conventional, low-input, and organic systems will have nearly equal yields for most crops in most years. The biggest remaining question is the comparative economic returns of using different off- and on-farm inputs, including skilled management, to maintain yield and quality under the different systems. Also important is the larger issue of market incentives and regulatory disincentives for more sustainable production practices, particularly for commodities produced in more diverse crop rotations. Business skill, experience, and knowledge, combined with creativity and flexibility, continue to characterize outstanding farmers. Perhaps more patience will be required for successful transition where variables such as the weather are concerned, but today's best conventional farmers probably will be among the leaders of tomorrow's transition.

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BOOK NOTICES

Fundamentals of Weed Science. Robert L. Zimdahl. 1993. Academic Press, 1250 Sixth Ave., San Diego, CA 92101-4311. xiv+450 pp. $54.95, hardcover.

This is intended as an introductory college text in weed science. Like many such, it devotes considerable space to herbicides. However, it regards herbicides as one tool in a larger set of techniques, including biological and other non-chemical approaches, and emphasizes an understanding of weed ecology as the foundation of weed management.

American Agriculture: A Brief History. R. Douglas Hurt. 1994. Iowa State University Press, 2121 South State Ave., Ames, IA 50014-8300. xii+412 pp. $34.95, hardcover.

This introduction to our agricultural history, from early Native American farming to the present, does not assume a prior knowledge of agriculture and would be suitable for a first undergraduate-level course. Its treatment is chronological, rather than thematic. Within each period, major topics covered include technology, markets, land use, agrarian agitation, and rural life. More specialized topics, such as sketches of important historical figures, are presented in numerous sidebars, and the book is illustrated with many historical photographs and drawings.

U.S. Agricultural Research: Strategic Challenges and Options. Robert D. Weaver (ed). 1993. Agricultural Research Institute, Bethesda, MD 20814. vi+380 pp. $22.00, paper.

This is a collection of 23 papers from a symposium held in 1992 that dealt with the forces for change in our agricultural research system and the possible responses. The authors are mainly from the land-grant colleges and USDA, but some are from other federal agencies or private companies. Among the forces for change are the increasingly stringent regulation of agriculture, tougher competition in international markets, increasing concern over food quality and safety, and the growing importance of biotechnology and molecular biology. Possible responses include changes in the institutional structure of the research establishment, new laws for protection of intellectual property, and different funding mechanisms.

Clean Water Act Should Support Sustainable Ag, Says New Report

Because polluted runoff from agriculture is the single largest source of water pollution, the Clean Water Act should adopt policies that support the mutual goals of clean water and sustainable farming, recommends a new report by the Midwest Sustainable Agriculture Working Group.

"Many conservation-minded farmers and those using sustainable agriculture methods are farming in ways that protect water quality," according to *Clean Water and Thriving Farms: Mutual Goals in Sustainable Agriculture*. "Nearly every principle of sustainable farming has a primary or side benefit that protects water quality."

The report categorizes the public policy approaches that are necessary to reduce polluted agricultural runoff in four categories: voluntary actions, incentives, removal of policy barriers, and regulation. The Group's report also lists 18 policy recommendations to address polluted runoff, including integrating environmental and agricultural policies, basing polluted run-off programs on watersheds, setting water quality standards for both nutrients and sediment, and establishing farmer and citizen water quality monitoring groups.

Clean Water and Thriving Farms is $5 from the Minnesota Project, 1885 University Ave. W., St. Paul, MN 55104; (612)645-6159.

Science and sustainability: An overview

Cornelia Butler Flora

Several themes emerged from this conference suggesting how science can be better linked to sustainability. Major themes that need to be addressed include: institutions and change; linkages among different groups involved in the food system, from producers through consumers; indicators of sustainability that encompass "quality of life"; changing the behavior of farmers and researchers to make agriculture more sustainable; and new approaches to research that are suited to alternative agricultures. Throughout the conference these themes were developed as farmers, researchers, and others exchanged their diverse viewpoints and experiences. These viewpoints are reflected both in the formal papers published in this issue and in the comments of panelists that I will draw on in trying to convey the major themes of the conference.

Institutions and Change

Institutions are created to serve a specific context. Yet often the context changes but the institutions do not. Stauber, Lockeretz, Batie and Swinton, and Francis (all in this issue) each address challenges faced by agricultural research and extension organizations and the inevitability of institutional change. Fifty years of expanding financial support helped to rigidify the system's structure, because new functions could be added without changing old ones. Many vestiges remain of institutional structures created to meet functions necessary early in this century. As long as the system was expanding, the new could be added at the margin without changing the old core. But with flat or declining funding, our agricultural institutions now must confront our past unwillingness to abandon functions that had become less important.

Land-grant institutions were founded in the mid 19th century to improve the condition of a large group of Americans who were disadvantaged socially and economically because of class (working), location (rural), and occupation (farmer). At the time, they were associated with a single sector—agriculture. Despite the lack of appropriate science to address these issues, land-grant universities were founded in state after state. As they evolved, many universities, particularly the portions that were still responsive to the land-grant mandate, gradually left behind their commitment to improve conditions by class, location, and occupation, but instead focussed on creating a strong sector. The people for whom the system was created lost importance, while what they produced took precedence. The rapid changes in technology at the land-grant universities to meet sector needs were not accompanied by institutional changes to keep the focus on human well-being. However, there is still a strong belief in some circles that what is good for agriculture (the sector) is good for farmers (the occupation) and their households and even for their communities (location). But these linkages are based more on assumptions than on systematic data. We need systematic research to determine how those categories are linked and under what conditions. Such knowledge will help us decide how to divide the work between public and private sector agricultural research, and whom to include in research and planning for a more sustainable agriculture.

The Cooperative Extension Service stemmed from the Country Life Commission, a group of concerned urbanites formed because of the huge gap between rural and urban standards of living and the concomitant rural to urban migration. The poverty of rural areas was a major concern, and increasing agricultural productivity was viewed as a way to improve human well-being in rural communities. However, it was easier to measure agricultural productivity than community well-being. Extension runs the risk of responding to the context of its founding, rather than the current times. Viewing farmers as less educated and therefore in need of information to solve specific problems (a top down approach) no longer will meet the needs of farm families, if it ever did. Farmer/extension educational *partnerships* are an exciting alternative.

The current fiscal crisis of both federal and state governments means that the research and extension functions of land-grant universities are under attack. Swinton and Batie (this issue) describe how land-grant institutions have responded to demands to address the issues of sustainability. But as Lockeretz (this issue) suggests, increasing the number of institutional partners in research is a way to broaden the resources available to agriculture. However, the relationships among these institutions will have to change.

Alternative models of delivery of alternative agricultural research and education will be part of a more sustainable agriculture. We are already seeing smaller and more innovative land-grant institutions moving into regional models of research specialization. Matching technology to the context where it will be used will be done by other researchers, with different kinds of preparation. Those researchers increasingly will be farmers. The mix and division of labor between public and private research institutions also needs to be

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considered. There is an important role for publicly supported research. Private input suppliers, in particular, are engaging in research on topics such as genetically engineered pesticide resistant varieties that would be the only ones that could grow on fields sprayed with their broad spectrum herbicides. Farmers and the environment will need other profitable technologies as alternatives—alternatives that increase the profit of the technology user, not its developer. We need to consider the appropriate role for publicly supported research, and the potential impact of that research on sustainability.

Extension, too, will change radically. Structural adjustment in developing countries has lead to massive privatization of extension, through for-profit service firms and private nonprofit organizations. These decentralized, privatized delivery mechanisms can be more flexible, more readily adaptable to local circumstances, and cheaper for local, state, and federal governments than cooperative extension as we know it today. Furthermore, farmers get much of their information on production techniques through input dealers and output purchasers, in forms ranging from command-control arrangements with integrated poultry and hog processors to advice on chemical use from the local cooperative or supply dealer. We need to consider seriously what kinds of technical information are likely to be forthcoming, and whether this increased role for the for-profit private sector leads to empowerment or dependency.

Last summer, I spoke to the annual meeting of agricultural extension agents in Washington, D.C. in a session on sustainability. I followed a speaker from the Economic Research Service who was starting a comparative study of the profitability of sustainable and conventional agriculture. The convener was thrilled, as we would have the answer, *once and for all*, of whether sustainable agriculture was profitable. Of course, we wouldn't know that, no matter how well the study was done. But why did the extension agents want it? Their role is defined as giving out the right answers to people's questions, and the simpler and more direct the question the better. Thus, a situation of hierarchy, dependency, and replication is set up. Reports can be filled out, county officials and state leaders can point with pride to numbers, and the farmer or grower, equally harried, can feel that if something goes wrong, it is because of the ignorance of the local land-grant institution. A contrasting approach is to ask the farm family to describe how their problems are related to their goals and their resources, and to identify the weakest link in solving them. They can formulate alternatives and make informed decisions that lead toward a more sustainable and better quality future for themselves and the agent. But this requires a major shift in roles and in power. This takes humility on the part of the researchers and extension workers who previously could claim the title of "expert." But it also takes a vision of one's mission and a strong sense of self-worth. Only those who are confident about what they know can reveal their own ignorance to find out what they do not know and identify what they think they know that may not be true.

Change in land-grant institutions will be uncomfortable. We have been used to 50 years of expansion at the margins. New money came into our institutions, allowing us to create new programs while keeping old ones. Now, however, when level funding is the best we can hope for, we must make choices that increase our discomfort. Saul Alinsky (1986) pointed out the discomfort associated with change:

> Where there is change, there is movement. Where there is movement, there is friction. Where there is friction, there is heat.

To what degree are land-grant universities prepared to use that heat to become more flexible?

Linkages

Stauber (this issue) notes that suburban values now dominate. We need to identify those values and work to maximize common ground. The Land Stewardship Project's linkages to urban groups through the churches is an example of how this can take place.

There needs to be a greater linkage between those who produce the food and those who consume it — but the same can be said about everything that is produced and consumed. The industrial moral economy separates all production from the consumer. If farmers want suburban consumers to learn about where their food comes from, they in turn need to learn how suburbanites produce the goods and services that vitally affect everyone's lives. Farmers and consumers need to understand what happens to food and fiber after it leaves the farm gate — not only who profits, but who does the work. Workers in the meat packing industry, the truck drivers who deliver the products, and many others along the food chain influence food quality and availability.

Linkages, whether between rural residents and suburbanites, farmers and environmentalists, land-grant and non-land grant researchers, or farmers and scientists, function best if they are partnerships. That means not only teaching "them" about "us" but also about what must be done. It means altering our ways of defining problems and setting goals. It means listening as well as talking.

Dependence on chemicals, with its implications for environmental damage, is probably greater in suburban than in agricultural areas. There are interesting possibilities for linkages that solve mutual problems, rather than imposing suburban "solutions" that in fact increase rural problems of sustainability.

Indicators of Sustainability

Sustainability includes economic viability, environmental soundness, and something called quality of life. Everyone knows what quality of life is, but we cannot seem to measure it. It involves farm households, rural communities, and the well-being of society as a whole. We need indicators of all these dimensions of sustainability, and we need to be systematic in reporting them.

Several innovative activities presented at the conference have attempted to solve problems of sustainability through practices thought to be more sustainable. The research teams, whether interdisciplinary groups of scientists or farmer-scientist teams, did a fine job of reporting measures of productivity and profitability using graphs, tables, and charts comparable to those used in conventional agricultural research. Distressingly, only a few of these

efforts present measures of changes in environmental soundness. A few present measures of soil health or soil quality, changes in water quality, changes in biodiversity, etc. It is generally assumed that the "alternative" practices are more environmentally sound, but typically no evidence is offered to support it. However, both Young and Temple (this issue) report specific indicators of environmental degradation. Also, while we are assured that quality of life is strengthened by a change to alternative practices, we do not have the data supporting that assurance. Even practices that are more environmentally sound and more profitable do not necessarily contribute to the quality of life of the rural community. Madeline Mellinger, a private consultant on more sustainable horticultural practices in south Florida, reported that only one of her 150 clients lived on the land they farmed.

Our challenge is to present sound, externally verifiable indicators of quality of life. Some farmer-driven research, such as that of Practical Farmers of Iowa (Rossman, this issue), include quality of life as an abstract goal in their research efforts. We now need to translate those goals into concrete, measurable indicators at the level of the individual, the farm or ranch, the community, and the landscape. These measures should be reported as regularly as yields, costs, and profits.

Changing Behavior to Become More Sustainable

Clearly, farmers are not the only ones who have to change if agriculture is to become more sustainable. A systems perspective shows that consumers and policy makers are important in determining what producers do and how they do it. For all these groups, when we decide what motivates behavioral change, it is helpful to understand the moral economy that frames their reality. Several speakers emphasized the problems inherent in an industrial model of agriculture. That model has implications for behavioral change.

Peggy Barlett (1993), in her recent book, *American Dreams, Rural Realities*, contrasts two moral economies that give us insight into motivations for change. One is the industrial moral economy, where an individual's work is oriented toward consumption. In industrial forms of production, which require high geographic mobility, place of residence is separate from place of work. Therefore status and sense of personal identity are gained through consumption. What you produce and how you produce it is secondary to what you consume, which is the only part of you that is visible to the community.

In contrast, in an agrarian moral economy, how and what you produce takes precedence over consumption. The quality of your work can be observed by the people who are important to you where you live. Indeed, high levels of consumption can be seen as contrary to establishing a sense of community, which in turn is vital to a sense of self. Households with an agrarian moral economy are more likely to develop technologies of thrift rather than technologies of consumption. In our society, the industrial moral economy dominates. In some regions, it can be compatible with a movement toward a more sustainable agriculture. But in others, the agrarian moral economy will need to be nurtured as part of changing behavior to be more sustainable. This will require change at the community level as well as in the household.

Researchers also need to change. Many constraints on doing research on more sustainable systems come from researchers themselves, as problems involving how and what to publish, how to handle unpublished data, and even authorship discourage them from participating in multidisciplinary teams that include agricultural producers. As with the policies that limit farmer behavior, institutions limit researcher behavior by regarding conventional agriculture and conventional ways of doing research as the only possible ones.

Accusing people of farming unsustainably is a very ineffective way to get them to change their behavior. In studies of agriculturalists moving toward a more sustainable agriculture, changed attitudes and behavior occurred when individuals were consulted for what they did that was right, rather than admonished for what they did that was wrong. The on-farm comparisons of alternative and conventional systems reported at the conference (Temple, this issue) underlined the need to develop mutual respect and appreciation.

Research Approaches Suited to Alternative Agricultures

Science pegged to sustainability would be radically different, according to both Stauber and Francis (this issue). It would require a systems perspective; it would require optimization of various values rather than maximizing a single value; it would require knowledge of the process, not just of a cause-effect relationship.

Sustainability is a process, not a set of practices. Francis (this issue) illustrates this beautifully in his futurist description of science and sustainability. David Schlegel referred to sustainability as a moving target. What is sustainable is highly related to context. Thus we should speak of alternative agricultures. There will be no single set of "Best Management Practices" that can insure that the various dimensions of sustainability are being achieved.

Alternative agricultures will be developed through a combination of social organization and scientific research. Several innovative research designs were presented and discussed at the conference. We also considered how we arrived at research issues. We need to concentrate on how to go from a systems approach, which is holistic, to a research design, which often must be reductionist. But a systems approach should guide even reductionist research efforts. George Bird's presentation suggested identifying key stimuli and responses in subsystems to help determine research priorities and questions.

Alternative agricultures will need many different research approaches. Several important innovations were presented that show new ways of building partnerships. For example, Temple (this issue) reported on the experience of researchers who carried out farmer-designed and farmer-managed research at the University of California-Davis experiment station. Randomized complete blocks with split plot designs allowed for comparisons using full size equipment. The study included measures of environmental impact, as well as productivity and profitability. But the process of putting together the project and deciding the design may have been as important as the specific research results or even the methods used. The focus was on

principles and processes, with resulting mutual education. Agreeing to limit advocacy and to share leadership reduced defensiveness.

Alternative agricultures will move away from binary approaches to problems, understanding that there is no single answer, and that each answer brings with it a new set of problems. Alternative agricultures will move from recommendations to participation. Research will provide only some of the information needed to move toward more sustainable agriculture. A major part of the continuing process will be changing social organization to offer better support to producers, farm workers, farm households, rural communities, and the urban and suburban areas that depend on them. To paraphrase Batie and Swinton (this issue), we want both to do the research right and to do the right research.

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New SCS Natural Resources Approach is Based on Sustainability

The Soil Conservation Service's new way of managing natural resources is based on ecosystem principles and focuses on "sustainability for current and future use," according to an SCS official who detailed the plan at the recent 70th annual Agriculture Outlook conference, sponsored by the USDA, which included dozens of speakers representing government, industry, and the public interest.

The new "ecosystem-based assistance for the management of natural resources" involves "all concerned participants in the decision-making process, provides incentives, and insures a productive nation in harmony with a quality environment," according to Diane E. Gelburd, Associate Deputy Chief for Programs. This approach is "a model of how environmental issues will be increasingly addressed in 1994 and beyond," and "is a more effective approach for protecting our environment for the benefit of all."

Focusing on managing the natural systems and processes that sustain resources, this new ecosystem-based approach is being provided for several reasons, she said. It "recognizes people as part of the ecosystem," and is systems-oriented rather than single resource-oriented. It contributes to the goals of public land ecosystem management by providing compatible assistance to those who wish to participate voluntarily on private, non-forested lands. It also focuses on sustainable use, with the objective "to assist land users with managing their natural resources for the benefit of families, their communities, and future generations."

Another speaker at the two-day conference was Michael Jacobson, Executive Director of the Center for Science in the Public Interest, who outlined three steps USDA should take to expand its efforts to support organic and sustainable agriculture, in order to reduce farmers' dependency on pesticides: finalize the regulations defining the term "organic," as required in the 1990 Farm Bill; work with states to encourage farmers to adopt organic or sustainable methods and "highlight to farmers and consumers the advantages of organically grown food;" and encourage states to boost taxes on pesticides and fertilizer, and "earmark those revenues to mount vigorous campaigns to reduce agri-chemical use and repair the harm they have caused."

Grazing Strategies Seek Sustainable Ranching

To assure continued viability of ranch grazing, strategies that are ecologically compatible and economically sustainable are being researched and identified, with funding from the SARE program. Traditional season-long methods of domestic livestock grazing are viewed by some as competitive with ecological objectives; whole-ranch analyses to address these issues are needed if ranchers are to adopt ecologically compatible grazing systems in Oregon and other Western states.

In this project, emphasis is placed on ranch level ecological impacts of different grazing systems; results for three sets of grazing strategies—traditional, management intensive, and capital intensive—are being analyzed and subsequently disseminated. The project is also determining the impact of alternative grazing strategies on ranch and livestock performance on riparian zone and adjacent upland conditions, wildlife habitat, and resident and anadromous salmonids.

For more information, contact Project Coordinator, Ludwig M. Eisgruber, Professor, Oregon State University, Department of Agricultural and Resource Economics, 232A Ballard Extension Hall, Corvallis, OR 97331; (503)737-1423.

Addressing the challenges of sustainable agriculture research and extension at land-grant universities: Radially organized teams at Wisconsin

G.W. Stevenson, Joshua Posner, John Hall, Lee Cunningham, and Jan Harrison

Abstract. *Researchers at land-grant universities are under pressure to widen their research objectives, which requires them to expand their inquiry from a disciplinary base to a systems level, to include farmers and nonuniversity organizations as research collaborators, and to communicate with broader sectors of the public, such as consumers and policy makers. However, there are few rewards for scientists who undertake long-term, systems based research. An approach that brings together multidisciplinary, multiprofession teams using a radial model of organization has successfully addressed these challenges in Wisconsin. A small "hub" manages the team, with the remaining participants linked to component task forces or "satellite" projects. This enables research to be done on both multidisciplinary and related single-discipline questions. Radially organized teams can attract diverse people with different time commitments and reward incentives. The research meets the criteria of public and academic audiences alike. For innovative research and extension efforts like radial teams to reach their full potential, larger institutional changes are needed within the land-grant system and professional agricultural societies.*

Key words: multidisciplinary team research, alternative agriculture, integrated cropping systems

Introduction

In applied agricultural research, the land-grant universities face several major challenges through the 1990s and beyond:

Challenge I: *To adopt systems-oriented, agroecological approaches that examine both the biophysical and socioeconomic effects of alternative farming systems.* Voices inside and outside the land-grant system increasingly are calling on agricultural researchers to expand their inquiry from a discipline base to a systems level (Schuh, 1986; Buttel and Busch, 1988; National Research Council, 1989). Behind these calls is the need to identify, evaluate, and implement agricultural systems that are "economically sound, socially acceptable, and environmentally compatible" (Lacy, 1993, p. 41). Some writers have focused on systems analyses in the biophysical areas (Duvick, 1990; Francis et al., 1990), others on the connections between the biological and the social sciences (Heberlein, 1988; Lacy, 1993), and still others on matters of social justice (Allen et al., 1991).

Challenge II: *To expand the circle of research and extension collaborators to include farmers and representatives of nonuniversity organizations.* Suggested additional participants include producers, and, where applicable, suppliers, processors, nonprofit environmental and consumer organizations, and representatives of government agencies (Busch and Lacy, 1983; Schaller, 1991). Such calls have several bases: the historical citizen/university dialogue envisioned under the Morrow, Hatch, and Smith-Lever Acts (Danbom, 1986); a growing awareness among private U.S. corporations that listening to customers is crucial (Deming, 1982; Peters and Waterman, 1982); and the success of farmer involvement in applied research in international agriculture (Chambers et al., 1989). Reasons for expanding the circle of research and extension collaborators range from raising the quality and relevance of the knowledge generated (Suppe, 1987; Stevenson and Klemme, 1992) to restoring the image of the land-grant system (Buttel and Busch, 1988).

Challenge III: *To communicate research results to broader audiences, including consumers and policy makers.* The range of citizen groups who are actual or potential constituencies for the land-grant university system has changed significantly since the system began in the late nineteenth century (Buttel and Busch, 1988). Consequently, land-grant scientists and educators should establish communi-

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cation with these new groups (Debertin, 1992). Particularly important are consumers and policy makers (National Research Council, 1989; Clancy, 1993), two groups with whom land-grant institutions historically have not communicated well (Buttel and Busch, 1988; Lacy, 1993). Not giving attention to these communication channels will prove increasingly costly as the public becomes more concerned about agriculture's impact on the nation's natural resource base and the food system (National Research Council, 1989; Gussow, 1991).

Multidisciplinary, multiprofession, radially organized teams can attract diverse groups of people to undertake various types of systems research and extension. In the next section we outline the radial model of team organization, an approach that offers particular advantages for addressing the three challenges listed above. Next we describe two team projects in Wisconsin that use this model. One is a case study; the other uses a traditional replicated research design to compare alternative production strategies. We then assess the radial model after three years of experience, and conclude by offering some thoughts on what else the land-grant universities must do to meet the challenges of the next decades.

Radially Organized Teams: The Model

Little attention has been paid to the organizational dynamics of effective multidisciplinary, multiprofession teams in university-based agricultural research. The radial approach to structuring applied research and extension teams was inspired by the work of several organizational theorists who emphasize participatory leadership and goal setting (Deming, 1982; Wright and Morley, 1989; Miller et al., 1990), adaptive divisions of labor (Perrow, 1979; Kanter, 1983; MacRae et al., 1992), and multiple reward structures (Weisbord, 1976; Peters and Waterman, 1982). Many organizations, including research institutions, traditionally have divided labor either by specialty (discipline-based departments) or by multiskilled units (task forces) (Weisbord, 1976). Radially organized teams allow both.

This model is so named because when viewed schematically it resembles a spoked wheel (Figure 1). The center or "hub" consists of a few systems-oriented collaborators. They are connected to "satellite" researchers who focus on specific, discipline-oriented problems. Within the hub is the "axle," the administrative center.

The responsibilities of the team's hub include focusing on overall project objectives, particularly the interdisciplinary or systems-level investigations, and helping the axle with day-to-day management. To accomplish these tasks, hub members must meet frequently to discuss developing situations. They also initiate new satellite activities, integrate the findings of the completed research, and direct the outreach components.

Other team members involved in satellite research have more narrowly defined objectives that fit comfortably into existing disciplinary approaches, such as monitoring weed management strategies, arthropod dynamics or farm economics. These activities can be either long- or short-term. The "spokes" or means of communication that connect the hub with the satellites include field visits, team meetings, progress reports, and telephone. The axle in this model consists of the principal investigators, who are responsible for helping the teams to function effectively and for dealing with external agencies, such as by soliciting funding and writing reports.

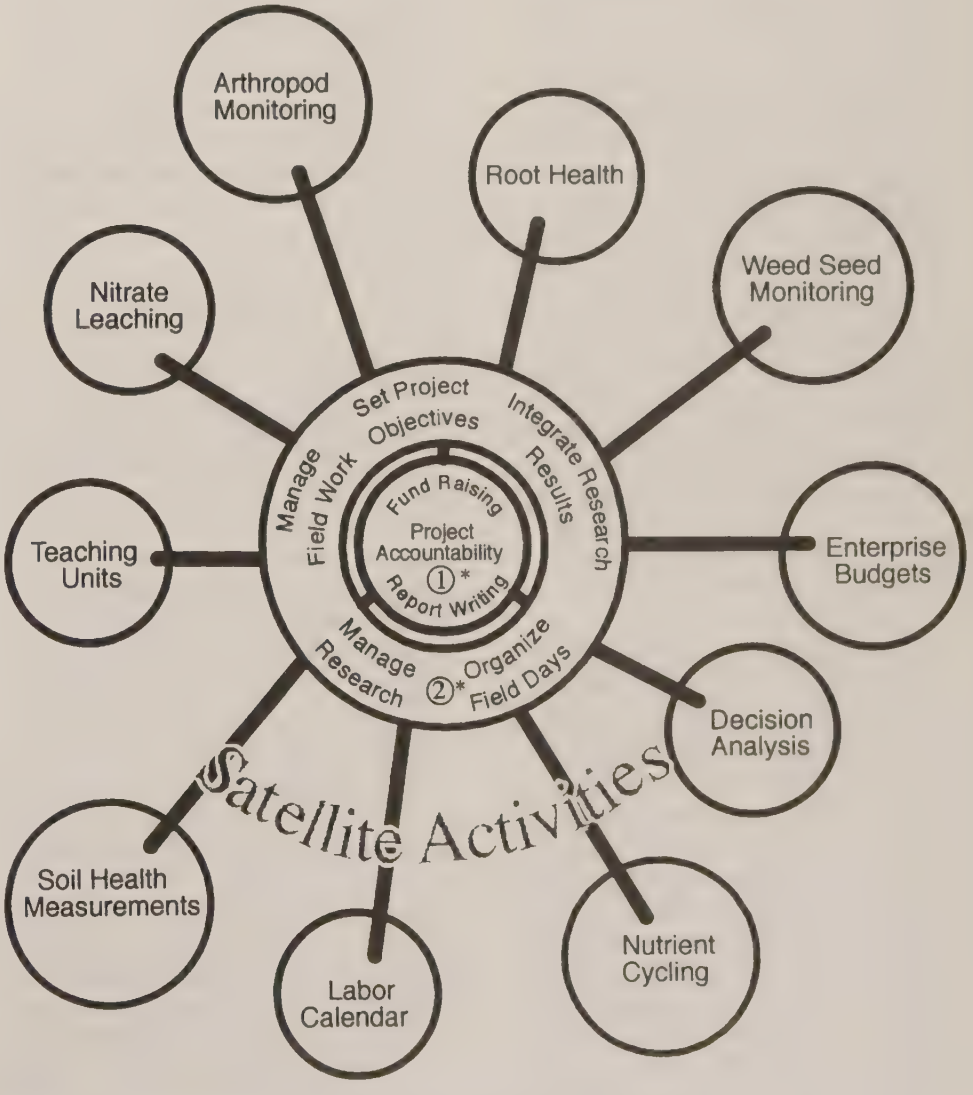

Figure 1. The radial model applied to Agricultural Systems Research

* ① axle activities, ② hub activities

In summary, radially organized teams do the following:

- They foster effective coordination of research and extension activities on multidisciplinary and related single discipline questions on a wide range of topics.
- They enable research coordinators to attract a wide range of university and nonuniversity participants with differing motivations, time commitments, and reward requirements.
- They allow satellite studies related to the core scientific explorations to be done according to different schedules.

Projects that Illustrate the Radial Model

Two Wisconsin projects currently employing the radial model of team organization are described in Table 1. One project, the Krusenbaum study, is a whole farm case study. Its objective is to monitor and assist a young farm couple as they convert a newly leased dairy farm from conventional to organic management. The other project, the Wisconsin Integrated Cropping Systems Trial, is a field-sized, replicated study that compares the productivity, profitability and environmental impact of six agricultural systems at two locations. Both projects began in 1989.

Forming teams and resolving conflicts over research design

With a general research hypothesis in mind (Table 1, Row 1), the principal investigators or axle members of each project began forming teams through ad hoc meetings to which they invited many potential team members. The primary tasks of these early meetings were to gauge people's interests and to choose the general research methods for each project (Table 1, Row 2).

Issues associated with alternative agricultural systems had been heavily politicized in recent years (National Research Council, 1989; Council for Agricultural Science and Technology, 1990; Potash and Phosphate Institute, 1990). Therefore, both projects gave high priority to insuring that the teams represented a range of philosophies so that future audiences would consider them "honest brokers." As Table 2 shows, the result was that the teams included a significant range of university scientists and other agricultural professionals. Because of the applied nature of the research, the scientific cores of both projects were recruited from university extension researchers drawn from the biological, physical, and social sciences. Farmer members of the Krusenbaum case study were selected because of their experience with systems that use reduced levels of purchased inputs. Farmer members of the Cropping Systems Trial, on the other hand, were chosen to represent a range of production strategies that paralleled the cropping systems being evaluated in the field-sized experiment.

About half the scientists invited to the initial meetings joined one of the projects. The primary reasons of those who did not were lack of time or objections to the research methods. These objections involved three methodological issues. First, several scientists discounted the Krusenbaum project because confounding phenomena are inevitable when an entire farming system is being studied, and because it is difficult to generalize from a case study. Second, a serious debate erupted in the early meetings of the Cropping Systems Trial between ecologists and production scientists. Expressing boredom with the simplicity of most agricultural systems, the ecologists argued for including a wide diversity of crops in the trials. The production scientists, on the other hand, wanted to limit the comparisons to economically reasonable alternatives. The project's hub developed a compromise consisting of six rotations, all potentially competitive economically, but ranging in complexity from continuous corn to controlled livestock grazing.

The last conflict was over farmers' power within the teams. The university scientists all accepted the principle of farmer participation in decision making, but several objected strenuously to the principal investigator's commitment to submit all research protocols to farmer evaluation, with the possibility of farmer veto. Scientists who felt most strongly about this withdrew.

A related disagreement was over how fast to release information from the research projects. Farmers and extension agents were concerned about the slow publication timetables of the university scientists. This conflict was resolved by scientists agreeing to present preliminary results at field days and through university departmental papers.

Involving a wide range of university and nonuniversity participants in the design phase resulted in a team of self-selected people for each project who felt comfortable working together and who agreed upon a common set of objectives (Table 1, Row 3). However, it quickly became clear that few participants in either project had the time to administer or coordinate the proposed research and outreach. The radial model of organization helped to resolve this impasse by accommodating team members' varying time commitments and research preferences. Table 2 describes the axle, hub, and satellite structures that eventually emerged for the two projects.

Using the radial model

Although the two projects have very different designs, their objectives are similar (Table 1, Row 3). Both emphasize understanding the biophysical and socioeconomic dynamics of the farming systems under study. Identifying and evaluating alternative production strategies figure strongly in both projects, and each team has made substantial commitments to educational and outreach activities.

As a result, there are many parallels between the two projects' hub activities (Table 1, Row 4). The first task of both hubs was to design the basic crop rotations. Other tasks included establishing data collection and measurement protocols for the performance of the crops and livestock and for economic and management indicators. Both projects hold winter meetings at which all members review plans for the coming season. Hub members meet regularly in the spring and early summer to implement timely changes in cropping plans. Additional hub activities include organizing field days, site visits and other educational programs, and annual team meetings to review project and team performance. Less coordinated effort is required for the satellite activities, which are component-specific and often shorter term. As described in Table 1, Row 5, these parallel

Table 1. Description of two Wisconsin projects employing the Radial Model of Organization

Project Title	The Krusenbaum Farm: A Case Study and Model in the Establishment of an Organic Dairy	The Wisconsin Integrated Cropping Systems Trial
1. Hypothesis	A low-input, sustainable agriculture approach is suitable for entry-level dairy farmers.	Increasing crop rotation diversity can maintain system productivity and profitability while reducing the need for chemical inputs.
2. Research Methods	A multidisciplinary case study of a family farm and its transition to organic farming.	A randomized complete block design comparing six rotations at two locations. Individual plots are approximately 0.75 acres.
3. Research Objectives	a. To describe the biological, physical, and financial effects of adopting low-input production practices. b. To chronicle the evolution of a set of coherent farm strategies to deal with issues of animal husbandry, debt management, and labor use. c. To develop tools that will permit generalizing from a case study to help others evaluate alternative production strategies.	a. To describe the biological, chemical, and physical impact of alternative crop rotations at the field level. This work will help promote an agroecological focus on farming. b. To quantify the short- and long-term economic implications of adopting alternative crop rotations. c. To expand the range of alternative technologies being presented to farmers. d. To build functioning "learning centers" that will involve diverse groups in community learning about agriculture.
4. Hub Activities	a. Conceptualize and evaluate an overall transition plan b. Design crop rotations to meet economic and organic objectives c. Develop and annually review the dairy herd feeding strategy d. Annually review compliance with ASCS and SCS regulations e. Annually review nutrient management and weed control programs f. Maintain farm records (e.g., agronomic, climatic, sales and purchases) g. Organize field days	a. Design the initial set of treatments b. Supervise the agronomic activities on the plots c. Modify treatments as the growing season progresses d. Develop the Learning Centers educational programs and field days e. Conduct site visits f. Edit an annual technical report
5. Satellite Activities	a. Redesign field boundaries to minimize erosion b. Weed monitoring and control strategies c. Evaluate milk production and herd health d. Analyze financial records e. Maintain decision diary f. Analyze building and machinery needs g. Monitor soil biological and physical characteristics h. Maintain labor diary	a. Monitor earthworm numbers b. Study the evolution of weed seed numbers c. Build phosphorous and potassium nutrient budgets d. Measure fall soil nitrate levels e. Describe changes in soil health f. Screen litter dwelling arthropods g. Take census of nematode populations h. Characterize corn root health i. Conduct economic analysis

Table 2. Team make-up of two Wisconsin projects employing the Radial Model of Organization.

The Krusenbaum Project	The Wisconsin Integrated Cropping Systems Project
Axle	
Host Farmer	2 Extension Agents
MFAI Agronomist[1]	2 Farm Superintendents
UW Agronomist[2]	MFAI Agronomist
	2 UW-Agronomists
Hub	
Host Farmer	6 Farmers
MFAI-Agronomist	2 Vo Ag Instructors[3]
Crop Consultant	2 Extension Agents
UW-Agronomist	2 Farm Superintendents
UW-Sociologist	MFAI Agronomist
UW-Economist	2 UW-Agronomists
Satellite Activities	
2 Farmers	2 Farmers
Crop Consultant	2 MFAI Agronomists
MFAI Agronomist	Master Gardener
8 UW-Ext. Specialists[4]	Land Conservationist
2 UW-Researchers[5]	SCS Soil Scientist
	9 UW-Ext. Specialists[4]
	7 UW-Researchers[5]

[1] MFAI = Michael Fields Agricultural Institute
[2] UW = University of Wisconsin-Madison Staff
[3] VoAg = High School Vocational Instructors in Agriculture
[4] University faculty with primarily an extension appointment
[5] University faculty with primarily a research appointment

explorations include agronomic, animal, physical, and farm management studies.

An Assessment of the Radial Model

Three years of experience with the two Wisconsin projects is enough to allow an initial assessment of the radial team model. The assessment focuses first on how well these radial teams have addressed the three challenges to the land-grant system posed earlier, and second on how well radially structured teams solve organizational problems generic to all team efforts.

The three land-grant challenges

1. *To adopt systems level research.* Both Wisconsin projects meet this challenge, with qualifications. Each focuses on an important system--an entire farm in one case, and a series of alternative cropping systems in the other. However, nearly all the analyses so far have been done in parallel rather than interactively. Agronomists compare nutrient cycling or weed ecology in the various cropping systems. Soil scientists focus on the systems' impacts on soil erosion or groundwater quality. Social scientists monitor the farms' labor use, management decisions, and profit margins. Helped by hub members and team meetings, such investigations result in important multidisciplinary as distinct from interdisciplinary research.

Some systems-level problem solving of an interdisciplinary nature has been undertaken in each project. The Krusenbaum team has worked interactively to generate dairy forage systems that comply with environmental standards, meet the herd's nutrient needs, and are suited to the farm family's labor and financial resources. As the literature suggests, truly interdisciplinary analysis is both required and facilitated by systems level problem solving (Birnbaum, 1982). Interdisciplinary efforts, however, require commitments of time and resources that only a few participants could make.

The varied research and monitoring activities of the two projects have resulted in the following types of output: case studies (Harrison, 1993); computer software packages (Vasquez et al., 1991; Baldock and Posner, 1992); Extension publications (Doll et al., 1992); departmental papers (Gumz et al., 1993); project reports (Posner and Hall, 1993); professional presentations (Posner and Casler, 1992); and professional journal articles (Stute and Posner, 1993).

2. *To expand the circle of research and extension collaborators.* Both Wisconsin teams have done well in responding to this challenge. As Table 2 reveals, both have farmers, county extension agents, scientists from non-profit organizations, and professional agricultural consultants as active members. Also, the Cropping Systems Trial includes high school teachers and the superintendents of the institutional farms hosting the investigations.

A greater challenge than recruiting these nontraditional research participants has been to obtain more than token involvement. As indicated above, the issue of farmers' power drove several prospective university scientists away when the teams were being formed. Both proactive and reactive organizational mechanisms have been used to give the nonscientists on the teams a sense that they are "owners" of the projects and exert real authority. First, the farmers, extension agents and research station superintendents were involved from the outset in setting the objectives and designs of both projects. This resulted in placing high priority on farmers' concerns

regarding the financial, labor, and management implications of the farming systems being studied and on the extension agents' concerns about the educational components. Second, nonscientists in both teams are empowered to veto project ideas that they collectively judge to be off the target.

3. *To communicate results to broader audiences, including consumers and policy makers.* As with the other two challenges, the Wisconsin teams have had qualified success in meeting this outreach challenge. A large number and good variety of people attended traditional field days sponsored by the two projects. Also encouraging has been the response to several innovative outreach activities generated by team members. These include elementary and high school curriculum units developed by the teams' county extension agents and public school teachers (Cunningham, 1992) and twilight meetings, cohosted with the Audubon Society, on the interactions between agriculture and wildlife. Attempts to communicate with state policy makers, on the other hand, have been only partially successful.

Organizational evaluation

Besides having to meet these three challenges facing land-grant universities, the radial teams at Wisconsin had to address organizational challenges that are generic to all team efforts, but are particularly important to these teams because of the mix of disciplines, professions, and political outlooks. To function well, radial teams must develop effective leadership and goal setting procedures, foster successful communication and conflict resolution, and insure that the necessary resources are obtained to reward and motivate team members (Weisbord, 1976).

1. *Leadership.* Effective leadership is critical in managing the varied activities of multiprofession radial teams. It requires the teams' axle and hub members to make a substantial commitment and to be competent both in scientific judgment and human relations skills (Anbar, 1973; Rossini and Porter, 1979). Commitment is required because leadership and coordinating duties often are frustrating and time consuming (Heberlein, 1988). As shown in Table 1, radial teams need substantial monitoring and adjusting. This attention is particularly necessary in agriculture, where participating professionals like university scientists and family farmers are accustomed to working independently.

Pivotal to the successes of both Wisconsin teams has been the leadership of an axle person who not only has a background in farming systems research but also has a mandate from the college to facilitate applied, multidisciplinary projects. Such job descriptions are rare in land-grant institutions. Also, both teams have profited from the inclusion of a social scientist interested in small group dynamics, another nontraditional area for agricultural researchers.

2. *Internal communication and conflict resolution.* These areas clearly show the importance of leadership and a center of team accountability. After experimenting unsuccessfully with more complex communication structures, both teams decided to transmit all significant information through one axle faculty person. Agendas for planning and communication are prepared by this team leader and carried out in several ways. The hub of the Cropping Systems Trial meets four times a year, while the Krusenbaum team hub has averaged over six meetings per year. The full teams meet twice a year, once before planting and once after harvest. Annual reports summarizing the various satellite studies also are important in communication.

Conflict resolution also is handled in various ways. Whenever possible, compromises are forged at team meetings, such as the compromise mentioned earlier between the ecological and production groups in the Cropping Systems Trial. When such resolution is not possible, the satellite studies and on-farm trials offer opportunities for conflicting sides to try out their preferences, such as testing the effectiveness of various soil additives.

As mentioned, veto power is important for both projects. An agreement was reached early in the Krusenbaum project that whenever the farm couple chose not to follow advice offered by the team, they would tell the hub why in writing. The Krusenbaums kept a decision diary that shows such veto power was exercised primarily when the couple believed that following the advice would require too much labor or would significantly set back the farm's transition to organic certification (Stevenson, 1993). The veto power exercised by the county committees of the Cropping Systems Trial was less aggressive, and usually involved recommending modifications of the satellite research experiments proposed by university scientists.

3. *Obtaining resources.* The marginal status of long-term, systems research is revealed by the difficulties that both teams have had in securing funding. One problem has to do with the research objectives. Since neither study focuses primarily on agricultural inputs, it is difficult to go to some traditional sources that fund applied research. On the other hand, neither study is sufficiently process-oriented to have access to funding sources for basic biological research. Timing is another problem. Neither long-term rotations nor farms in transition are in equilibrium during the early years, so that few conclusions can be drawn with short-term funding.

Finally, academic prejudices appear to play a role. The Research Committee of the Graduate School at the University of Wisconsin, for example, rejected funding for the Cropping Systems Trial with the justification that the school "should not fund projects that do not potentially help faculty to develop research programs fundable by federal agencies like NIH, USDA, NSF, etc." The committee twisted the knife deeper by commenting to the principal investigator that its funds "should go to projects with clearly stated hypotheses and methodologies used in creative ways" (!) (memo to Joshua Posner, December 12, 1991).

On the positive side, support for the two projects has been secured from nontraditional funding sources, including the University of Wisconsin's Center for Integrated Agricultural Systems (Stevenson and Klemme, 1992), the Wisconsin Department of Agriculture, Trade, and Consumer Protection, the Wisconsin Department of Natural Resources, USDA's Sustainable Agriculture Research and Education program, and the Kellogg Foundation.

Summary

Our experience shows that radially organized teams of scientists, farmers, and other agricultural professionals can make important contributions to sustainable agriculture research and extension. Areas

identified for further work and development include:

- Doing truly interdisciplinary research to complement multidisciplinary and single discipline investigations.
- Broadening the acceptance of the contributions that nonscientists make to multiprofession research teams.
- Developing creative outreach strategies to communicate with wider sectors of the agricultural community, particularly policy makers.
- Generating new sources of funding and support for long-term, systems-oriented agroecological studies.

To address these challenges successfully, significant institutional changes will be needed within the land-grant system and professional agricultural societies. These changes include:

1. Broadening the public research agenda beyond the traditional orientation toward agricultural production issues and the recent emphasis on the molecular and cellular levels (Bonnen, 1986; Buttel and Busch, 1988). This will mean seriously upgrading the attention given to such topics as ecological systems, whole farm and community analyses, and matters of class, race, gender, and intergenerational equity in agricultural and food systems (Allen et al., 1991).

2. Modifying institutional structures to give a clear mandate for integrating high quality science with systems-oriented applied research and outreach programs. Encouraging efforts to do so are occurring at centers of integrated or sustainable agricultural systems on several land-grant campuses across the country (Lacy, 1993). Such efforts, however, need to be institutionally structured at higher levels of organizational authority and integration (Weiss and Robb, 1989; Beattie, 1991).

3. Altering the flow of resources and rewards to create incentives for interdisciplinary research and outreach efforts. Examples include devising ways to credit multiple authorship fully (Friedhoff, 1988), securing space in prestigious journals for reporting high quality, systems oriented research (Heberlein, 1988), and revising job descriptions and tenure evaluations for new faculty hired to provide leadership to effective multidisciplinary and multiprofession teams.

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UPCOMING EVENTS

July 15, *Minnesota Cattlemen's Association summer tour* will start in Mora, MN; contact Steve Kruse, (612)689-3756, or Terry Salmela, Minnesota Extension Service, (612)679-3010.

July 20-24, *Two Years After UNCED: Exploring Partnerships for Sustainable Development* will be held in Davenport, IA; contact Patrick Frese, Event Management Unlimited, 2224 East 12th St., Davenport, IA 52803; (319)324-4941.

July 20, *Sustainable Agriculture and Integrated Pest Management Field Day* will be held at the Beltsville Agriculture Research Center, USDA, ARS, Beltsville, MD; contact Don Bills or Dana Lamberti, (301)504-7338.

August 5-7, *Northeast Organic Farming Association 20th Annual Summer Conference* will be held at Hampshire College, Amherst, MA; contact Julie Rawson, 411 Sheldon Road, Barre, MA 01005; (508)355-2853.

Tufts Offers Master's Program in Agriculture, Food, and Environment

Tufts University's School of Nutrition, in collaboration with the Department of Urban and Environmental Policy, has a new master's program in Agriculture, Food, and Environment, which addresses growing interest in the interconnections among environmental, social, nutritional, and safety aspects of food production, and the need to consider all those aspects in developing solutions to problems in any one area. Students are admitted through the School of Nutrition on a rolling admissions basis for the Spring and Fall semesters. For more information, contact Lori Anderson, Coordinator of Student Services, School of Nutrition, Tufts University, Medford, MA 02155.

COMMENTARY

Some ideas and guidelines for research on ecological agriculture

Joachim Raupp

Abstract. *Research on ecological agricultural systems should not confine itself to their biological and technological aspects, but should also deal with their social and human implications. Moreover, the goal should be to improve ecological agriculture, not just to document the performance of existing systems. Comparative studies of ecological versus conventional production systems are not adequate to achieve this goal. We need a broad research program that deals with fundamental agroecosystem processes, socioeconomic questions, appropriate livestock production systems, food quality, and information transfer among farmers and others. Research strategies on several levels are needed for this purpose, such as pot and field experiments, case studies, and modeling.*

Key words: agroecology, agricultural research methods, animal husbandry, socioeconomic research, information transfer

The special characteristics of ecological agriculture are often described with terms such as *holism*, *cyclic*, and *systems approach*. These terms, some of which are more meaningful and applicable than others, refer primarily to production techniques and goals. However, such a perspective encompasses only part of what farming is about — the part captured by the processes and conditions of natural science and technology.

Agricultural systems are very complex in their structure and function. They consist not only of biological but also of economic and social elements. Besides concerning ourselves with plants, animals, breeding, manure and tillage, it is critical that we also deal with factors like self-fulfillment, social recognition, and people's expectations and anxieties about the future. We can understand an individual farm fully only when we consider its social context. Therefore, research must take account of the economic and social elements that shape the farm and affect its surroundings.

I will use just one example from the literature to show how agroecosystems are being analyzed with respect to socioeconomic indicators, not just ecological categories like producers, decomposers, and consumers (Bick, 1989). According to Conway (1987), the goal of agroecosystems is to add to social value (in the sense of welfare theory), both now and in the future (Table 1). He further identifies four primary characteristics of agroecosystems. At least two of them (productivity and stability) are valid for ecological systems in general. The concept that probably will be most surprising is the fourth: equitability. Productivity, stability and sustainability—that is, the response of the system to disturbance—are amenable to ecological treatment, but equitability is a uniquely social variable. These concepts go far beyond the properties of a lake left in its natural state, for example, where knowing its biotic and abiotic components and its surroundings is enough for us to describe and understand it satisfactorily. This is not true for agroecosystems, however, because they include social and economic components and processes. (This general idea also was outlined by Geng et al., 1990.)

Conway understands "equitability" as referring to the just distribution of results of production. But we are being too narrowly economic if our goal is only to meet consumers' needs; we must see justness as encompassing much more. It obviously must include the people in agriculture; without question they should have socially just and ethically defensible living and working conditions. We especially should not forget this in ecological agriculture, which sometimes is more labor intensive than agriculture in general. Moreover, the problem of overwork and the social conflicts that result from it often occur in ecological agriculture research, which still is a marginal field held in low regard, and which therefore suffers from personnel shortages and tight budgets. If, in the name of ecological agriculture, we are working to develop systems that are ecologically, socially and ethically defensible, there is a discrepancy between the goal and the reality if we do not fulfill this goal in our everyday working conditions. As one agricultural scientist (who shall remain nameless) was heard to say: "O.K., we want a socially

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Table 1. Conway's (1987) characterization of agroecosystems.

The Goal of Agroecosystems:

- Increase in social value (in the sense of welfare theory) today and in the future

Primary characteristics of agroecosystems:

- Productivity
- Stability
- Sustainability
- Equitability

compatible agriculture. But must we begin with ourselves?" (No comment.)

Another area where greater justness must be achieved is in how we keep animals. The goal of justness for the animal and the species has been incorporated into our criteria for an agricultural system. We now must find evaluation measures and husbandry methods that let us develop an agricultural system that functions well both socially and biologically, and that is ethically defensible. This should be true throughout agriculture, not just in ecological agriculture. Nevertheless, the standards placed on ecological agriculture often are higher than elsewhere.

The Goals of Research

The following suggestions are offered just as examples, with no claim that they are complete. I start with the question: What is our goal in pursuing research? To me, the leading task of ecological agriculture research is to analyze and improve ecological agriculture as a system. We should be able to understand its essence and its positive and negative consequences. With this understanding, it should be possible to work out solutions to practical problems, on one hand, and on the other, to advance the system itself, to find new approaches that are preferable not just technically but also ecologically and socioeconomically. This means that research has a service role: helping with problem solving and system development. (The functions of research are not exhausted by this role, but I will not be discussing its more far-reaching functions of acquiring knowledge and deepening our understanding of nature. Another important point not discussed here is the personal aspect of research, which each scientist must explore individually: What is the significance of doing research for my personal life and for the development of my personality, and what are my qualifications for doing this work in particular?)

In the past—often this is still true—the goal of research was not to develop better ecological agricultural systems, but instead to describe and analyze them. Therefore, the method of choice often was the comparative study. Consequently, we have many interesting and important results comparing ecological and conventional agriculture. From today's vantage point, however, and looking toward future needs, I believe that comparative studies no longer are necessary. They hardly contribute either to the advancement of ecological agricultural systems or to sound causal analysis of them. I do not know a single ecologically managed farm where problems were solved with the results of comparative studies. Similarly, I do not know any farmers who decided to convert to ecological methods because of such studies.

These studies mainly have had the character of demonstrations. People wanted to learn and then show which agricultural system was better or poorer, in whatever way. However, such comparisons are not useful for putting the results to work in agricultural practice. I will grant that comparative studies are interesting personally for me in teaching. For example, I can use them to show students how soils develop after 20 years of ecological management compared with conventional management. This is interesting and meaningful when studying agriculture, even if comparative investigations do not let us directly identify the reasons for the differences in soil development, which is why I do not consider them suitable for causal analysis. The advantages and disadvantages of comparative studies have recently been discussed by Lindenthal and Hess (1993). They consider it necessary to concentrate future research capability on further methodological advances in ecological agriculture. For more than three years I have presented this view in lectures at various colleges and other public institutions. The counterargument often was raised that comparative studies are useful mainly because of the learning benefits for the investigator. However, can the (possible) learning benefits for the investigator justify the high costs of comparative studies?

Beyond Comparative Studies: System-level Questions

I would like to develop some requirements for research concerned with fundamental analysis and improvement of ecological agricultural systems, using three principles (Table 2). Above all, research in ecological agriculture demands that in posing questions we keep the entire system in view. Individual measures are important through their connections and interactions with the entire farm and their effects on the surrounding landscape and on society.

Without presenting an exhaustive description of such work, I will offer some examples of system-level research themes. We should investigate every possibility for controlling the soil's biological activity and for regulating pest populations through the full spectrum of cultural practices. Applying such practices is essential for the functioning of ecological agriculture. Often we have only a vague knowledge of the underlying dynamic regulatory mechanisms of agroecosystems. The same is true for the possibilities of intervening to make the system more stable, intrinsically more productive, and less sensitive to extreme conditions, such as bad weather and pest outbreaks.

A further example is research to design animal husbandry systems that are appropriate for the species and the individual animals with regard to their surroundings and housing, diet, and veterinary treatments. Here, too, we must develop concepts suitable for understanding and improving the livestock enterprise in relation to the entire farm.

A third example of a system-level research question is evaluation of the socioeconomic effects not only of new inputs and practices but also of social and political factors such as agricultural subsidies. Such evaluations should be done *ex ante*, not just *ex post*. Program decisions usually

Table 2. Three principles for research to analyze and improve ecological agricultural systems.

1. Ecological agriculture research requires that we pose system-related questions.

Examples:

- Control of soil biological activity by soil and plant treatments
- Regulation of pest populations by soil and plant treatments
- Designing livestock enterprises appropriate for the species and the animal (surroundings, diet, veterinary treatments)
- Economic and social effects of production inputs and methods (*ex ante*, not *ex post)*
- Information transfer in all directions among scientists, advisers, practitioners, administrators, upstream and downstream sectors.

2. Ecological agriculture research requires research in neighboring fields.

Examples:

- Fundamental research on resistance physiology, weed biology, soil biology, etc.
- Agroecological foundations, for example, nutrient relationships, dynamics of regulation
- Food quality: criteria, analytical techniques, susceptibility to being influenced
- Socioeconomic questions connected with ecological agriculture

3. Ecological agriculture research must be conducted with tools appropriate for various levels.

Examples:

- *In vitro* and *in vivo* experiments
- Pot and field experiments
- Case studies
- "What-if" scenarios and model-building
- Integration with social science tools.

are made and implemented by the agricultural policy people, with researchers analyzing them only a year or two later. With luck, the matter turns out the way the politicians had expected when they introduced the program. Often that does not happen, however, which limits the significance of the research results in the politicians' eyes.

In contrast, I would hope that we obtain more input from the scientific side during the planning phase. Having more scientifically grounded information is essential before we embrace an innovation. This is true even for a new tillage technique or a new cultivator, for example. When a cultivator is put on the market, obviously we should know how suited it is for controlling weeds, which species it works well against, and which ones it controls only poorly. But the secondary effects of new implements and techniques should be investigated too, such as the cultivator's effects on soil structure and humus content. How well a new silo paint works should be known before it is marketed and used; it should not first be learned "accidentally" years later, after an action is brought against the farm because of residues in the milk.

Another area that can contribute a great deal to the improvement of ecological agriculture systems is information transfer, in all directions among all participants. This is especially true for information exchange among scientists, farm advisers, practitioners and administrators, but it also applies to the upstream and downstream sectors.

I consider the task of scientists is more than just to generate results that permeate practice through farm advisers. With applied research, there must be more feedback and suggestions in the opposite direction, especially from advisers to researchers. This does not mean that researchers must set up an experiment whenever a question arises. Often, sufficient practical guidance can be obtained from contact with other institutions or from the literature. For a multilevel system like ecological agriculture, exchange among people with different experience and backgrounds is highly advisable. How this exchange can be developed and institutionalized is itself an interesting research subject.

Research in Related Fields

Another point that I consider very important is that research on ecological agriculture can gain something essential if supporting research is undertaken in related fields (Table 2), especially the natural science disciplines that can make fundamental contributions to ecological agriculture. Relevant topics include physiology of resistance, weed biology, and the biology of soils and humus, as well as nutrient relationships, nutrient cycles in agricultural landscapes, and dynamic control processes in agroecosystems. Our knowledge in these areas is not complete enough for us to deal with them in a directed, purposeful way, in keeping with ecological agriculture's concept of working *with* natural processes, not against them.

The desire for more research activity in related fields refers especially to agroecology. However, this science often sees itself as a repair shop, concerned mainly with investigating and controlling the environmental damage caused by agriculture and other activities. Thus it often has the frustrating experience that between determining damage to the environment and undoing or preventing it come tedious proceedings that are vulnerable to so much political and economic influence and interference.

Instead of analyzing damage and thereby reducing it (perhaps), agroecologists can formulate their assignment positively to provide important guidance for

the theory and practice of ecological agriculture, a form of agriculture that, therefore, is purposefully founded upon ecological knowledge. If agroecologists engage in this assignment more vigorously, in the future there will be less environmental damage for them to investigate.

A further area of related research is food quality. What does it consist of, how can we measure it, and how can we affect it in agricultural practice? We would like to know more about agricultural systems to improve how well they achieve their primary goal of producing nourishment.

My final example of related research involves socioeconomic questions connected with ecological agriculture. This requires interdisciplinary research projects involving psychology, sociology, and pedagogy to investigate the connection—more accurately, the discrepancy—between knowledge and actions. Knowledge about ecological connections and problems is applicable to many everyday situations, but people do not necessarily take the corresponding actions (Langeheine and Lehmann, 1986). I see such behavior as an additional obstacle to the development of ecological agriculture and many other innovative endeavors, besides the economic obstacles that are commonly mentioned.

An Appropriate Diversity of Research Tools

My final principle relates to how research is conducted (Table 2). The preceding suggestions on themes and content demand a multi-tier toolchest appropriate for pursuing research on several levels. To deal properly with the system character of ecological agriculture, we must work with an integrated set of tools, bringing together and advancing all the classical tools of experimental research. *In vitro* experiments are as meaningful and justified as pot and field experiments if we are investigating specific techniques or specific biological processes at the subsystem level, for example. For analyzing complete management systems, case studies are an important tool (see Lampkin, 1988, for example). For evaluating outcomes and risks or for simulating systems, dynamic models and scenario-building techniques are required. In ecological agriculture, such tools are still at an early stage of development. In the future they should be used more vigorously.

In planning every project, we must consider which partial questions will be addressed using which natural or social science tools, and how the partial results can be tested in relation to the complete system. Investigating a specific problem in its full breadth, therefore, demands coordinated work that cuts across specialties. This requires that we use various tools that can be adapted to each other to yield sound, self-consistent answers. Today a fragmented disciplinary structure prevails not only in agricultural research but also in highly specialized curricula. The question is whether this structure is suited for the mode of research just described, or at least can prepare students for it in the future.

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Current Economic Policies Discourage Sustainable Ag, Says WRI Report

Current economic policies worldwide promote inefficient and environmentally damaging practices that discourage the adoption of sustainable agriculture, according to a new research report by the World Resources Institute. Reviewing six international and U.S. case studies, the report concluded that "agricultural sustainability is given little weight in economic policy-making," and also found that economic subsidies encourage the inefficient use of inputs and resources. When changes in the natural resource base are included in calculating farm income, the report found, resource-conserving practices can compete economically with conventional ones.

Among the report's recommendations that would encourage sustainable agriculture and economic development are to eliminate subsidies that encourage natural resource degradation or depletion; to eliminate agricultural support programs that distort economic signals for farmers, creating surpluses that entail heavy fiscal costs and excessive environmental damage; to have decisions on public funding for research take into account the environmental costs and benefits of the research; and to have national economic indicators of the agricultural sector reported in official statistics reflect the depletion and degradation of natural resources.

Agricultural Policy and Sustainability: Case Studies from India, Chile, the Philippines, and the United States, 113 pages, is $14.95 plus $3 shipping from WRI Publications, P.O. Box 4852, Hampden Station, Baltimore, MD 21211.

BOOK REVIEWS

The Dairy Debate: Consequences of Bovine Growth Hormone and Rotational Grazing Technologies. Edited by William C. Liebhardt. 1993. Sustainable Agriculture Research and Education Program, University of California, Davis, CA 95616. $31.50, paper. xvii+372 pp.

Two important recent developments in dairying have been the availability of recombinant bovine growth hormone (rBGH, also called bovine somatotropin, or bST), and the growing attention paid by farmers and researchers to intensive rotational grazing (IRG). The former is more controversial and has been more in the news. However, the latter is very significant too, because it involves a major shift in how we think about the role of livestock in sustainable agricultural systems. For years many people have believed that reducing the role of livestock products in our food system would make our agricultural system more sustainable because more resources are consumed in meeting nutritional needs through livestock products than through nutritionally equivalent crop products. However, IRG systems, which are probably the most successful sustainable system today in rainfed temperate areas by both economic and environmental criteria, are livestock production systems. This has prompted a long-overdue reevaluation of the role of livestock in sustainable agriculture.

An interesting reflection on the rise of IRG is the volume *The Dairy Debate*, perhaps the first book on North American sustainable agriculture to focus exclusively on livestock. However, it is devoted more to rBGH than to IRG itself. Why so? The book is structured around a comparison of the "relative merits of [these] two distinctly different technologies being promoted for dairy farmers" (p. ix). The authors of most chapters in *The Dairy Debate* make this comparison by conceiving rBGH and IRG as alternative roads or paths of technological change that will have collective social, economic, and environmental impacts. Given the collective nature of the decisions that will be made about using these two technologies, the authors aim to assemble a base of data that will prompt farmers and public policymakers to grapple with the long-term social and environmental implications of rBGH and IRG.

Before commenting on the book as a whole and its individual chapters, I should note that this material became very controversial well before the book was published. Liebhardt published a two-page summary of the book in the Winter 1992 issue of *UC Davis Magazine*, the university's alumni magazine. In it he stressed that rBGH and IRG are not merely individual technologies, but also collective social choices, and he also placed considerable emphasis on problems with rBGH technology. The next issue of *UC Davis Magazine* (Spring 1993) included an article and three letters that attacked Liebhardt and his research in a way seldom seen in an alumni magazine. Because the critics included the dean of the college of agriculture, the associate dean for cooperative extension, and the chair of the department of animal science, this outpouring looked like the land-grant wagons being circled yet again. This response by college officials to Liebhardt's work prompted a further round of 13 letters published in the Summer 1993 issue of the magazine. The writers of these mostly angry letters, including UC-Davis faculty members, extension specialists and agents, and farmers, either protested the treatment of Liebhardt by college notables or defended his approach.

The Dairy Debate consists of eight chapters and a useful six-page executive summary. It is very interdisciplinary, with its authors including a nutritionist, two veterinary scientists, three agronomists, two economists, a political scientist, and a freelance writer. But despite the diversity of the authors, the book largely has a coherent argument. Gail Feenstra, for example, marshals impressive evidence from several surveys that have consistently revealed that consumers are likely to resist rBGH-produced milk products, which would be a significant threat to the milk market. David Kronfeld's long, technical paper emphasizes some shortcomings of rBGH and the risks it may pose to public health, such as the indirect risk from the increased use of antibiotics required to control the higher incidence of mastitis among rBGH-treated cows. Articles by Liebhardt and by William Murphy and John Kunkel report case study results from farm-level experiences with IRG. Edward Rayburn's chapter makes the case that rBGH technology, by reinforcing confinement feeding and encouraging large-scale dairying, will compare poorly with IRG with regard to water pollution, soil erosion, and other environmental criteria. David Campbell argues that IRG is superior to rBGH in its effects on the structure of dairy production and therefore on agricultural communities.

The paper by Bees Butler and Gerry Cohn on the economics of rBGH and IRG differs considerably in tone from the rest. These economists do not come down strongly on one or another side of the "dairy debate," but instead confine their argument to demonstrating that IRG is a viable technology that economically is at least as promising as rBGH. But the overall message of the book, summarized in the Executive Summary and Kathleen Byrnes' concluding paper, is that IRG is more sustainable, more socially just, and less risky than rBGH, and thus is the socially preferable collective choice.

The UC-Davis officials who felt the need to ridicule Liebhardt did, however, raise one important question in assessing *The Dairy Debate*: whether it is meaningful to present the issue as a choice *between* rBGH and IRG. The alumni magazine article co-authored by the UC-Davis associate dean for extension, the chair of dairy science, an extension nutritionist and, interestingly, Bees Butler, noted that Liebhardt has "offered consumers an imaginary choice .... Rotational grazing is an alternative to confinement feeding, not to the use of bST."

Liebhardt's administrative colleagues have made a good point here. rBGH and

IRG are not, strictly speaking, alternatives, in the sense that a farmer would choose one over the other to solve a particular production problem. The authors of *The Dairy Debate* would have done well to explain more precisely the ways in which rBGH and IRG do and do not represent a meaningful choice. But I suspect that ultimately they are correct. Five or ten years from now we are likely to find that in practice there will be few dairy farmers who use both rBGH and IRG. That is, farmers mostly will have chosen one over the other as a way to enhance profitability or respond to environmental concerns. Also, public policymakers are now making at least an indirect choice between the two, such as when dairy science departments decide to emphasize one over the other in their extension programs or in allocating their research herds and experiment station plots.

The Dairy Debate is a very useful overview of current data and literature on two important emerging technologies in dairying. It should be on the bookshelf of anyone interested in the future of dairying or in IRG. Even more important, it provides a glimpse of something we need much more of in the land-grant system: interdisciplinary *ex ante* assessments of emerging technologies. I particularly admire the notion of Liebhardt and associates that emerging technologies should be assessed comparatively, since comparisons can best help policymakers, scientists, farmers, and citizens make more informed choices.

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Deep Disagreement in U.S. Agriculture: Making Sense of Policy Conflict. By Christopher Hamlin and Philip T. Shepard. 1993. Westview Press, San Francisco. $42.50, paper. 309 pp.

This book moves beyond particular issues in agriculture to consider underlying ideologies that lead to deep disagreements on a wide spectrum of issues. Hamlin and Shepard propose that communication about policy issues should bring to the surface the diverse ideas about nature, human nature, knowledge, social order, and practice that are implicit in the philosophies of policy advocates. Rather than supporting any particular set of ideas, they come forward as intellectual mediators whose aim is to help readers understand the differences and convergences among several alternative philosophies. As a result, besides the content of this analysis, the process itself emerges as a contribution.

The first five chapters make the case for being more explicit about ideologies so that we can move public discourse beyond polarized positions. (Ideologies are defined here as "the network of symbols with which we shape our response to the world, understand our place in it, and plan and carry out our actions.") The next six chapters compare three representative ideologies in detail. For this purpose the authors chose the Kentucky writer and farmer Wendell Berry, representing "radical humanism"; National Farmer Organization activist and *Acres USA* editor Charles Walters, representing "ecological progressivism"; and the 1983 Battelle Memorial Institute's report *Agriculture 2000*, representing "conventional productivism."

A few examples show the kinds of comparisons central to this book's analysis. Since agriculture involves the use of natural resources, ideas about nature and the proper human relationship to nature are implicit in much talk about agricultural problems and policies. Both Walters and the Battelle report see humans primarily as increasingly skillful managers of nature who use and transform natural resources for human purposes. In contrast, Berry sees humans within the cyclical yet always mysterious processes of nature.

Thus both Walters and the Battelle report focus on ways that agricultural scientists can improve the work of nature, while Berry focuses on the need to accept the limits implied by natural cycles and to appreciate the lessons learned by reflecting on them. However, Walters differs from the Battelle report on another level, where he is closer to Berry. Walter's theistic ideas see nature as the creation of the divine, reflecting an intelligent plan, while the purely scientific viewpoint of the Battelle report sees nature simply as the "a collection of raw materials, each with its own interesting properties." Thus both Berry and Walters have reasons for attending to what may be called "the wisdom of nature," whereas this metaphor would not make sense in the Battelle report, which is more concerned with the dictates of economic factors and technological possibilities.

Throughout, the analysis is filled with intriguing smaller points such as the reflection on ways that trends are given normative significance by Battelle. Trends become both driving forces and tracks into the future, so that "riding the trend" is the path toward success, with those outside the trend seen as deviant resisters against powerful social forces. This, of course, is exactly what allows conventional agricultural ideology to ignore the questions posed by thinkers like Berry. The mediator role chosen by the authors is seen in the way they remain carefully descriptive rather than openly supporting or opposing the obviously powerful approach of the Battelle report.

The final two chapters analyze how ideologies similar to those of Berry, Walters and Battelle appear in the legislative process and in formulation of research agendas. Using the 1980 plant patenting legislation as an example, the authors show how Congressmen and speakers could not present clearly the ideologies behind their judgments nor understand clearly the ideological basis for differing views. This inability led to confusion, misunderstanding, and a focus on short-term action as a solution to the deep disagreement. Here, Hamlin and Shepard step aside from their dispassionate analysis to argue for more in-depth hearings in which underlying ideologies are made more explicit. Similarly, they argue that bringing to the surface the philosophies implicit in research agendas might allow discussion of how they shape recommendations.

The major strength of this book is its focus on drawing ideology into the open, not so that one or another discussant can be proved "wrong," but to improve communication about agricultural policy. The authors' work here parallels the larger movement toward multicultural education that rejects the assumption that one historic culture is absolutely "right" or "best," moving instead toward understanding the context of diverse cultural attitudes and appreciating the contributions each has made to

a rich global civilization. The ideas in this book have similar strengths and difficulties.

One strength is that granting respectful attention to each agricultural ideology helps shift the focus from argument toward a cooperative effort at understanding. Although this will clarify that some differences are irresolvable — for example, humans either do or do not have the right to manipulate all of nature for their purposes — points of common interest also will emerge. For example, the Berry, Walters, and Battelle ideologies all see the need to ensure healthy natural resources for the future, although what counts as "healthy" can be debated. Instead of treating one perspective as the whole picture, the exercise of ideological analysis put forward in this book leads to seeing that each ideology asks different questions, has different strengths, and omits different factors. The result is that diversity of agricultural ideologies could be seen as helpfully complementary instead of just antagonistic.

In practice, the process of discerning and discussing diverse ideologies would demand both new analytic skills and a deeper level of cooperative attentiveness than is usually found in the hectic legislative process. Those requirements would be magnified by the wide diversity of ideologies present in policy discussions. Berry, Walters, and Battelle do not, of course, encompass all the diverse ideologies at work in American agriculture. Indeed, one weakness of the book is an implication that these three do represent major points on the spectrum of agricultural ideologies. I suspect that an analysis of the ideologies of scientists engaged in alternative agriculture research might show strong variations from any of the three categories provided. Berry and Walters may be valuable here not so much because they represent large segments of the agricultural community but because their writing so clearly shows their ideology, thus providing excellent case studies for analysis. Moreover, the authors do not focus as clearly on the commonalities of the three ideologies as they do on the differences. Yet discernment of common long-range goals is a central step in aiding both communication and cooperation.

But these points do not detract from the important direction suggested by Hamlin and Shepard. It is vital that we have processes that pull away from the deeply entrenched battle-language and combative consciousness that are common in American political discourse, and instead help achieve deeper understanding of diverse ways of thinking. This is especially true as the United States moves toward respect for multicultural perspectives at home and internationally toward agreements whose negotiations require us to understand even more diverse cultures. Hamlin and Shepard have described not only a process but a new kind of professional in the policy process: intellectual mediators whose work this book sets forth. The next step is to move toward workshops and university courses that teach such philosophically and culturally reflective communication skills.

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Data for Agrarian Development. By C.D. Poate and P.F. Daplyn. 1993. Cambridge University Press, 40 W. 20th St., New York, NY 10011-4211. $79.95, hardcover; $32.95, paper. x+387 pp.

Understanding and solving the problems of agricultural and rural development in poorer settings demands professionals who are well trained and skilled in gathering and interpreting agrarian data. C.D. Poate and P.F. Daplyn, drawing on their extensive agricultural development experience, have contributed a book to the Wye College Studies in Agricultural and Rural Development that offers solid principles, techniques, and applications for the collection and use of information. They prepared the book while working for the Agricultural Projects' Monitoring, Evaluation and Planning Unit of the Federal Government of Nigeria. The following statement by the Wye editorial board about the series as a whole applies very well to this book: "The series provides simultaneously a systematic basis for teaching and study, a means of updating the knowledge of workers in the field, and a source of ideas for those involved in planning development" (p. iv).

The authors' style and approach provide both beginning and seasoned teachers and students with a participatory learning environment directed to research and evaluation. Recognizing that secondary information sources usually are not available in resource-poor settings, and that primary data collection often is not done with sufficient prior information to meet desired statistical standards, the book gives many options for meeting the challenges to applied problem solving research under less than optimal conditions. The book is a "hands-on" text that moves from principles through techniques to applications in each subject area for a broad range of situations often encountered in survey research. It begins by anchoring the researcher in an appreciation for careful survey planning (Chapter 1) and an introduction to sampling (Chapter 2). Fundamentals of sample survey design, including variability, precision, confidence, staging, clustering and stratification, are presented for ease of understanding by the beginner, yet under "real world" circumstances that will challenge experienced researchers (Chapter 3).

Chapters 4 through 6 focus on data collection and measurement methods applicable to various study units. A challenge in survey research is identifying the unit of study appropriate to the problem that motivated the investigation. Among the many useful examples in the book, in Chapter 4 the authors discuss the rural Nigerian family unit as one needing careful definition before data collection on family activities is initiated. The family or communal unit as a whole contains household units, economic units, production units and individual nuclear units, each an important source of data. Specific units of observation include fields, plots, crops, plants and livestock, villages, leaders, the sexes, and markets. Throughout the book, care is given to examples like the Nigerian one that enhance the learning process for aspiring survey researchers. Current data collection and measurement methods are being challenged by environmental concerns, with the units of observation being redefined to deal with problems such as reduced-chemical agriculture with sustainable resource use. Poate and Daplyn provide for both the creativity and the experiential insight to meet such challenges. Along with the clear and useful presentation of ques-

tionnaire design, field work and data processing (Chapters 7 through 9), the reader is exposed to good management and human relations practices in information gathering: "Fieldwork management is an essential part of such quests for good data quality. It is both internal, concerned with the timetable of work, training and documentation; and external, dealing with government agencies, other surveyors, community leaders, and the welfare and performance of the field workers" (p. 7). The strengths and weaknesses of alternative techniques for observation and measurement give the survey manager several approaches to varied situations.

The authors recognize that research is not complete without good communication of the results. They offer appropriate and effective means and examples, including various statistical and graphical techniques to illustrate exploratory analysis, estimation, comparative analysis and presentation of results (Chapters 10 through 12).

Besides communicating well in general, the book includes short flow diagram summaries within each chapter for use as visuals by the teacher. It also has an ample glossary that defines statistical and study unit terms, a list of references to broaden the learning environment, and an extensive "quick access" index. One appendix assists with estimating parameters and another is concerned with detecting fabricated data. Depending on one's perspective, this book can meet the needs of various formal or short courses, or it can replace several less inclusive and less applied references for the traveling evaluator.

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Ogallala: Water for a Dry Land. John Opie. 1993. University of Nebraska Press, 901 North 17th St., Lincoln, NE 68588-0520. $35.00, hardcover. xxi+412 pp.

Ogallala: Water for a Dry Land is a study of the use and depletion of the Ogallala aquifer, especially in the Dust Bowl region of southwest Kansas, southeast Colorado, and the Texas and Oklahoma panhandles. It is both an historical survey and a prescriptive public policy tract on one of the great "tragedies of the commons" in our times, though it does not fill these dual roles with equal facility and success.

Opie is at his best in recounting the history of the Dust Bowl region, its frequent and legendary struggles with aridity, its post-World War II exploitation of groundwater resources, and its increasingly urgent attempts to slow the depletion of the aquifer. A skilled and accomplished historian of technology, Opie handles such arcane matters as pump design with as much confidence and deftness as he shows when explaining the geological history of the Ogallala or John Wesley Powell's theories on aridity in the West. Unfortunately, a few errors creep in that a diligent reader should have caught, such as Opie's absurd contention that "we are losing five feet of topsoil each year" (p. 305).

Another of Opie's strengths is as a patient and perceptive interviewer. His sections on family farmers and water conservation districts, which draw heavily on his conversations with relevant informants, are especially instructive and valuable. The book is worth its price for these sections alone.

Where Opie falls short is on the public policy side. One problem is that his style makes it difficult for the reader to see where he is going and what he believes in. He uses what might be called the "on the other hand" mode of analysis; every time he makes a clear and strong point he vitiates it by balancing it with a contrary opinion. If he quotes Wes Jackson on sustainability in Plains agriculture, for example, he balances him with some agricultural economist from the USDA. Further blunting Opie's points is his tendency to overuse the passive voice. This is a social science technique that is meant to convey objectivity, but that in reality often represents a refusal to take a clear stand.

In Opie's case, on-the-other-hand composition and passive voice are indications of muddled analysis. Opie believes that food production from the Ogallala region is necessary to meet world food needs, a dubious proposition to be sure, but one that undergirds his contention that agriculture in the area must achieve environmental sustainability, meaning that eventually the depletion of the aquifer must end.

The rub is that Opie also believes that small-scale "family farm" agriculture must also be made sustainable for national social, economic, and spiritual purposes. He believes "family farmers" are valuable because they have special knowledge that might be lost if they disappear, and because they are "independent." He sees no contradiction between this last contention and his tacit recognition that farmers are highly dependent on government programs, a galaxy of agribusiness firms, and, more to the point, Ogallala water. Nor does he recognize that the highly capitalized producers of whom he writes can hardly be said to fit most reasonable definitions of "family farmers." When an irrigation system for an average farm costs about half a million dollars, it is difficult to see the producer as a latter-day Jeffersonian yeoman.

Opie paints himself into a corner here and throws away the key, to paraphrase that popular philosopher Archie Bunker. It is not possible in light of present or foreseeable affordable technology to make the old Dust Bowl region both environmentally and socially sustainable. A dry farming regime will not provide an acceptable standard of living to the population presently on the land, and while conservation might reduce the rate of groundwater depletion, it can only delay, not prevent, what seems inevitable. Despite his excoriation of such water demons as Iowa Beef Processors and Mobil Oil, it is mainly the "family farmers" who are sucking the aquifer dry. Consequently, Opie's plea for an environmentally and socially sustainable region is more pious hope than practical plan.

Still, even those who find Opie's prescriptions unsatisfactory will find much to admire in a book that ranges widely over history, technology, geology, climate change, water law, and other subjects. Its breadth alone makes *Ogallala: Water for a Dry Land* a valuable contribution on an important subject.

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Sustainable Agriculture and the Environment in the Humid Tropics. Committee on Sustainable Agriculture and the Environment in the Humid Tropics, National Research Council. 1993. National Academy Press, 2101 Constitution Ave., NW, Washington, DC 20418. $49.95, hardcover. xv+702 pp.

Sustainable agricultural development in the humid tropics carries with it a daunting array of controversial themes: foreseeing the long-term consequences of sustained agricultural output; addressing productivity problems in developing country agriculture; shaping agriculture to address human needs and social policies; maintaining the sustainability of ecosystem function and process; and so on. Accordingly, the analysis of sustainable agriculture does not fall within the purview of a single discipline or empirical field of inquiry. It requires interdisciplinary synthesis and in-depth case materials from Africa, Asia and Tropical America.

After the UN Conference on Environment and Development in 1992 and the subsequent creation of the global Commission on Sustainable Development, a volume such as this is particularly welcome. The National Research Council is among the most interesting sources of syntheses on several environmental questions. The authors of this volume are eminent students of agricultural development, deforestation and tropical agroecosystems. With advocates of tropical conservation and tropical agriculture at each other's throats much of the time, the appearance of this volume sparks hope that the sustainability debate might be treated to a dose of solid, down-to-earth analysis.

In fact, the book does offer a comprehensive synthesis of literature from the humid tropics, ranging from a survey of land use history and alternatives (really more of a catalog of agricultural practices in the tropics) to the values behind sustainable agriculture and the quest for broader "sustainability" in fragile ecosystems. The case studies of Brazil, Cote d'Ivoire, Indonesia, Malaysia, Mexico, the Philippines and Zaire constitute the bulk of the volume, which is preceded by a lengthy general text on the humid tropics. The case study authors are well known specialists who bring to the volume a deep understanding of their countries' political and agricultural systems.

Despite its prodigious size and the experience of its contributors, the book has limits. Perhaps wisely, it does not delve into the definitional wrangle that has surrounded sustainable development, into which sustainable agriculture surely must fit. Sustainable agriculture is defined in a general way as "broad spectrum of food and fiber production systems suited to the varied environmental conditions in the humid tropics. These systems attempt to keep productive capacity of natural resources in step with population growth and economic demands while protecting and, where necessary, restoring environmental quality" (p. 66). This general definition permits the Committee to focus on management and technical issues that are important to the volume's efforts to make "practical" recommendations for action.

The problem with this definitional imprecision is twofold. First, it allows the volume to wander because of a lack of conceptual guidance. In the Brazilian case study, for example, the authors define sustainable agriculture in terms of "permanence [of agriculture] in an area," "increasing land and labor productivity standards" and an implied "equilibrium in time among agroeconomic and/or zootechnical, economic, ecologic, and social feasibility" (p. 266). But in their honesty the authors immediately retreat from this bold set of criteria by admitting that no land use system in the Amazon can meet these standards. After that admission, the authors gravitate toward sustained agricultural output on technical and agronomic grounds. Sustained output is a poor substitute for sustainability.

The second problem, which is more serious, is the authors' reluctance to define sustainable agriculture in a conceptually rigorous fashion. This means that the central questions facing humankind are never asked clearly and unequivocally: Sustainable agriculture for what? What are the human and ecological values that underpin sustainable agriculture? Sustainable agriculture includes sustained agricultural output over the long run, improved agricultural productivity, a better distribution of agricultural output, improved rural incomes for the poor, enhanced preservation of pristine forests, and maintenance of soil cover against erosion among its goals. But in what measure, with what priorities? The volume points out these questions at various points, but never really takes them on directly.

The authors equivocate on another critical issue: the population question. They correctly note that they do not take on the role of population in sustainable agriculture or in land degradation because it is outside their purview and beyond the scope of the volume. Yet, they often blame population pressures for land degradation (Brazil, Cote d'Ivoire) or wonder at the ability of previous systems to sustain greater population densities in tropical areas on a relatively sustainable basis (Mexico). Because the volume avoids analyzing population variables as such, the reader is left with allusions and surmise, but not the kind of forward-looking analysis that is needed.

To their credit, the authors make several aggressive statements in favor of better stewardship of landed resources in the tropics. They call for clearer appreciation of native technologies and indigenous knowledge in general, and address sustainable use of the humid tropics as an issue of the global commons, that is, they correctly identify the global importance of site-specific scientific and social questions. In the executive summary, they call for the protection in perpetuity of the pristine forest (p. 4), a goal that has been mentioned in conservation circles more than in agriculture in recent years. Yet the matter of figuring out what constitutes the pristine forest is ignored. In the Mexican case study, the authors note that many areas previously considered to be pristine are now known to have borne human impact for centuries. The same certainly could be argued for Brazil and Indonesia, among other countries with "pristine" tropical forest settings.

Finally, the volume is unclear on where responsibility and solutions lie. The authors agree that developed countries have a responsibility to bear some of the costs (p. 172), but less because of the global commons argument than because of their history of benefitting from tropical land use. Developed countries set the terms of world agriculture to a much greater extent than is recognized in the volume's case materials. Most of the book focuses on national and local policies that mitigate land abuses (titling and tenure, lo-

cal participation, better resource management techniques, developing improved market signals), but little attention is paid to the tropical products trade disputes in the General Agreement on Tariffs and Trade, or the preferential rationing of market access in the European Community or the United States. From import substitution in agriculture to tropical plantation crops (bananas, sugar, coffee, etc.), the North helps determine the agricultural systems of the South. Without addressing the role of the rich countries and the international system directly, sustainable agriculture in the humid tropics is unlikely.

Sustainable agriculture is a pragmatic value incorporating notions of benign agriculture for a hungry world. Whether or not agriculture is sustainable in the humid tropics depends very much on the definition of sustainability, the identification of beneficiaries and victims of the process, and the recognition that agriculture anywhere is measured by initiatives and rules made at the international system level. This volume contributes a worthwhile prologue to understanding those dynamics and underlying values, but readers still are left with an imprecise notion of sustainable agriculture that has only a limited connection to ecological sustainability. The literature on sustainable agriculture has been well served by this volume, but to link agriculture to sustainability requires analysts to incorporate much more than agriculture in their conceptual reach.

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Soil Specific Crop Management: A Workshop on Research and Development. Edited by P.C. Robert, R.H. Rust, and W.E. Larson. 1993. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. 677 South Segoe Road, Madison, WI 53711-1086. $20, paper. 406 pp.

The concept of soil specific crop management (SSCM) has been described by many other terms, including soil specific farming, farming on the grid, farming by soil type, farming by the foot, farming soils not fields, variable rate technology, best management practices, prescription farming, and precision farming. Increased interest in SSCM appeared in the mid-1980s and is likely to continue well into the 21st century. With growing awareness of environmental problems and the need for resource conservation, soil specific crop management makes sense; this book therefore is timely. It contains 22 invited papers, 6 working group reports and 15 poster summaries presented at the First Workshop on Soil Specific Crop Management, held in Minneapolis, Minnesota in April 1992. The workshop had three objectives: to review current knowledge and application technology in soil specific management; to outline the research needed for adoption of the full range of agronomic practices (tillage to harvest) for soil specific management; and to identify development and technology transfer needs. The book highlights the current and future research and development issues on six topics: soil resources variability, managing variability, engineering technology, profitability, environment, and technology transfer.

The first of its seven sections deals with variability of soil resources, with a keynote paper by Bouma and Finke. Soil resources vary because of geological and pedological processes that must be understood when assessing soil variability in the field. For agricultural land use, important land qualities are soil moisture availability, soil nutrient status and nitrate leaching potential. Process-oriented simulation models that integrate nutrient fluxes in soils and crops are suitable for determining these qualities. Site-specific crop management can be facilitated by delineating relatively homogeneous soil management zones, using geostatistical techniques to determine the optimal grid size. The paper on terrain analysis for SSCM contains an excellent review of how the primary topographic attributes can be computed from digital elevation model (DEM) data. It illustrates how several hydrologically based, topographically derived indices can be used to identify land that is susceptible to environmental hazards and soil degradation. The discussion paper identifies five operational levels to focus discussion on issues. (The authors refer to a Fig. 5-1 but it is missing from the chapter, leaving the reader lost.) Nevertheless, the research and development issues from level 1 (data acquisition for establishing management zones) to level 5 (development of simulation models) are well explained.

Section 2 deals with factors to be considered when managing variability. It discusses the importance of getting site specific information in a suitable format for making computerized fertilizer and pesticide recommendations. Several examples are given of soil fertility management in an easy-to-understand language. The chapter on tillage describes how information on within-field variability from a soil mapping unit database can be matched with various options for controlling tillage-induced soil changes to provide a better seed and root environment and to conserve soil and water better. The paper on weed studies stresses the need for a careful description of weed distribution in applying geographic information system (GIS) techniques. Is management of within-field variability worthwhile? Forcella points out the economic and environmental implications of differential management of within-field variability. The discussion paper identifies six areas of research needs: data capture and analysis, experimental designs and protocols, integrated crop management, soil taxonomy and database utility, machinery and sensors, and cost/benefit/risk analysis.

Section 3 contains three papers on engineering technology describing sensors for yield, moisture, soil organic matter and soil chemistry currently available in Europe and North America. Further development of sensors and control systems may encourage widespread adoption of SSCM. Tyler discusses global positioning systems (GPS) and explains the principal ways they are used, particularly in agriculture. Further development of these technologies no doubt will affect automated agriculture. Chapter 14 on decision support systems (DSS) explains how a user can judge whether a database meets the information requirements for a decision. The authors illustrate the basic components of a DSS and the AEGIS (Agriculture and Environmental Geographic Information System) in easily understandable language with schematic diagrams, and give detailed descrip-

tions of a database management system (DBMS), models, expert systems, and GISs.

Three papers in the section on profitability compare the cost and returns of farming by soil (FBS) and the conventional system. The case studies from the Midwest show that costs are higher for the FBS program because of special application equipment, additional soil sampling and analysis, data management, and mapping. Nevertheless, variable rate fertilization shows promise as a profitable practice with potential environmental benefits. Unfortunately, the paper on site specific experience is poorly written; data in the tables are not well presented and units are missing in most tables.

The section on environment consists of five papers, including two on the effects of agricultural practices on water quality. The keynote paper by Randall describes best management practices for efficient nitrogen use in Minnesota. It is based on the concept that accurate determination of crop N needs is essential for profitable and environmentally sound N management. The second paper points out the need to consider the socioeconomic setting when introducing SSCM.

The paper by Gustafson describes ways to use soil data and computer models to minimize impacts on water quality. Marks and Ward review available information on nutrient pollution and pesticide contamination of water in the U.S. and explain how soil testing provides the basis for computerized, color-coded maps to match fertilizer and pesticide application rates to yield goals, thus helping to reduce pollution at the source. The discussion group identifies soil attributes, tillage/residue/fertilizer/pesticide management, and landscape position as important factors in assessing the impacts of soil specific management.

The section on technology transfer includes some of the best papers. The paper on prescription farming describes the benefits and problems involved in adopting variable rate technology (VRT). The second paper describes VRT from a dealer's viewpoint and highlights some limitations in technology transfer. The third highlights the importance of computerized record keeping for VRT, which requires a sophisticated integration of computerized equipment, software, databases and decision aids. It correctly points out that few groups have the computer experience or personnel to implement this complex technology. The discussion group identifies retail dealers and crop consultants as critical to the adoption of SSCM technologies and describes strategies for educating these two groups.

Section 7 consists of summaries of poster papers. Although details are lacking, many contributions contain useful and innovative ideas.

I recommend this book to researchers in agronomy, soil science, and environmental science and to extension workers. Geographers, engineers, and geologists also would find it useful.

M.A. Arshad, Research Scientist, Soil Physics and Management, Agriculture and Agri-food Canada, PO Box 29, Beaverlodge, Alberta T0H 0C0, Canada.

From the Ground Up: Rethinking Industrial Agriculture. By Peter Goering, Helena Norberg-Hodge, and John Page. 1993. Zed Books, Ltd., 165 First Ave., Atlantic Highlands, NJ 07716. $49.95, hardcover; $17.50, paper. viii+120 pp.

If you are looking for a concise overview of the problems of industrial agriculture, and a visionary look at the worldwide movement toward ecological agriculture, you should get this wonderful little book. Its three authors are associates of the International Society for Ecology and Culture (ISEC), a non-profit organization based in Bristol, England and Berkeley, California. ISEC's primary goal is to promote critical discussion of various elements of modern industrial civilization, such as its high energy, pesticide intensive system of agriculture, while seeking alternative strategies for a more sustainable way of life. One of the authors, Helena Norberg-Hodge, Director of ISEC, is perhaps best known for establishing the Ladakh Project in Tibet, and for the summary of that experience in her 1992 book *Ancient Futures: Learning from Ladakh* (reviewed in *AJAA*, Vol. 8, No. 3).

From the Ground Up is divided into two almost equal parts: Industrial Agriculture: Broken Promises; and The New Agriculture: Back to Basics. Part 1 discuses most of the major problems of modern industrial agriculture, such as its overemphasis on specialization, standardization, and centralization (Chap. 1); the relationship between corporations, seeds, and declining genetic resources (Chap. 2); the environmental and health effects of using chemical fertilizers (Chap. 3) and artificial pesticides (Chap. 4); the factory nature of our system of animal husbandry (Chap. 5); our overreliance on fossil fuels (Chap. 6); and the decline of the family farm and the associated increase in regional poverty (Chap. 7). It concludes with a timely discussion of "free" trade, GATT, and biotechnology (Chap. 8).

I particularly like how Part 1 clearly identifies some root problems of our modern system of agriculture, such as its intensive use of (if not blind faith in) science and technology to solve all problems; its increasing trend toward a narrow perspective through specialization; its drive to "homogenize" through standardization; and its demand for an economy that is highly integrated into world trade. What the authors fail to emphasize, however, is that these characteristics of industrial agriculture apply generally to modern industrial societies as a whole. Reversing the course of "modern" agriculture also will require a shift in how we think about and use our other natural resources, including energy, nonfuel minerals, forests, grasslands, wildlife, and freshwater and marine resources (Klee, 1991). Many parts of the world have experienced an agricultural revolution (beginning some ten thousand years ago in Mesopotamia), and an industrial revolution (beginning about 225 years ago in Europe). However, another revolution, that is, a revolution in thinking, will have to occur before there is any real change in our present industrial agricultural system. Perhaps one day historians will record that the modern U.S. environmental movement that began 25 years ago with the offshore oil blowout in Santa Barbara, California, was the beginning of an environmental revolution that again changed national and international ways of viewing and working with the earth.

Regardless, one can help move the nation and world toward a more environmental paradigm by rethinking industrial

agriculture, which is exactly the subject of Part 2. Chapter 9, "The Context of Ecological Agriculture," is only three pages long, yet it accurately identifies and discusses seven essential ingredients for ecological agriculture: *holistic thinking*, instead of the reductionist, mechanistic view; *a sense of humility*, rather than scientific arrogance; *generalism*, rather than the perspective of the specialist; *diversity of nature*, not simplified monocultures; *smaller scale farming*, not mammoth, energy intensive, fossil fuel dependent systems; *decentralization*, rather than centralized political and economic power; and *responsibility*, rather than corporate structures that often overlook principles of good land stewardship.

Chapter 10, "Learning from the Past," is among my favorites because it recognizes the value of studying indigenous or non-Western agricultural strategies from around the world. U.S. agriculturalists and modern resource managers clearly have much to learn from the long-standing conservation practices of traditional societies (Klee, 1980; in press). This notion is further supported by the numerous national and international organizations that study traditional agriculture, such as Iowa State University's Center for Indigenous Knowledge for Agriculture and Rural Development. Some newly established journals are devoted specifically to learning, protecting, and preserving indigenous knowledge related to natural resource perception and use, for example the Mexican journal *Etnoecológica* (Ethnoecology).

From the Ground Up then goes into the techniques of ecological agriculture, such as nurturing soil fertility and cultivating genetic diversity (Chap. 11). Chapter 12 deals with positive trends, such as the changing attitudes of farmers and the increasing demand for organic products. The concluding summary, "Counterdevelopment" and New Ways Forward, is a wrap-up of a viewpoint stated earlier: that we should always question science—where it is leading society, and whether this evolution is really "progress." An additional point in this last section is a new role for education: "to restore respect for agriculture as a profession and to reflect the diversity of environments and cultures" (p. 90). How many educators in urban centers today encourage their students to pursue farming or gardening as a profession? Very few, I suspect. Although I teach at an urban campus in the heart of "Silicon Valley" (a valley of silicon chips and computers where apricot orchards once stood), I still encourage my students at least to consider a career in which they can work closely with the soil.

The book also has an appendix that gives a brief background on some of the philosophical leaders in alternative agriculture, such as Wendell Berry, Masanobu Fukuoka, John Jeavons, and Wes Jackson. More importantly, it lists the names, addresses, and telephone numbers of 27 organizations that disseminate information and maintain directories of local contacts related to sustainable agriculture. It also has an up-to-date reference list and a useful index.

I have only one complaint about this book, which is its many many typographical errors. Something is seriously wrong when even undergraduate students complain about the number of misspelled words in an assigned reading. Apart from this flaw, I recommend it to teachers and students alike as a concise and highly readable argument for rethinking industrial agriculture "from the ground up."

Gary A Klee, Professor, Department of Geography and Environmental Studies, San Jose State University, San Jose, CA 95192-0166.

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Congressman Farr to Form Sustainable Ag Working Group

U.S. Representative Sam Farr (D-CA), a member of the House Committee on Agriculture, is establishing a working group on sustainable agriculture in Congress. One of the key purposes of the working group will be to keep Members of Congress informed of the progress of the National Organic Standards Board and the compliance of the Federal Organic Foods Production Act of 1990, according to the Congressman's office. Another key objective of the group will be to ensure that the organic foods industry is fully acknowledged in the 1995 Farm Bill.

When he was a California state legislator, Congressman Farr was the author of the California Organic Foods Labelling and Enforcement Act. For more information about the working group, contact Linda Delgado in the Congressman's Washington office, (202)225-2861.

IPM Catalog Illustrates Acceptance of Alternative Pest Controls

A catalog that specializes in products designed to help commercial growers raise successful crops without chemicals owes its continued success to "effective applications of IPM practices," according to an article in the January/February issue of *In Business*. Pest Management Supply, Inc., entering its 14th year in business, has experienced steady sales increases, averaging about 15 percent per year.

"The growth of [the company's] non-chemical products illustrates the commercial acceptance of the IPM method," according to the magazine. Among the products the catalog offers are insect traps, field microscopes, sweep nets, computer software, pest monitoring devices, biological pest controls, and a weather intelligence system that forecasts insect and disease activity, giving farmers an idea of what to expect and how to plan for it. For more information, contact Pest Management Supply, 311 River Drive, Hadley, MA 01035; 1-800-272-7672 or (413)549-7246.

Grading Standards Could Include Pesticide Information, Suggests USDA

Modifying federal grade standards or establishing a certification program to include information about pesticides might help consumers signal their preferences to growers and packers for produce with fewer pesticide residues, according to *Federal Grade Standards for Fresh Produce: Linkages to Pesticide Use*, a report recently published by the USDA.

"Little evidence is available regarding the effects of grades on pesticide use," the report found, adding that research is needed to measure relationships between pesticide use and product appearance, and consumers' tradeoffs between product appearance and freedom from pesticides. Among the policy alternatives listed in the report that "merit consideration" are not changing the standards; lowering the external appearance standards; modifying the standards to include information about pesticide use during growing and packing, and pesticide residues; and adding a pesticide testing and monitoring program separate from both grades and standards and current efforts by the Food and Drug Administration.

Copies of *Federal Grade Standards for Fresh Produce: Linkages to Pesticide Use* (AIB-675) are $9 from ERS-NASS, 341 Victory Drive, Herndon, VA 22070; or call 1-800-999-6779.

Biological Nematode-Control Techniques May Help Sugar Beet Growers

Sugar beet growers may be able to reduce their dependency on pesticides with biological pest control of nematodes, which is now being studied by researchers funded by the SARE program. Researchers are adapting a system that has been employed successfully in Europe to the growing conditions and climates of the western United States; that system provides sugar beet growers with an environmentally safe means of cyst nematode control. Cooperators in each of the three major sugar beet-growing areas of Wyoming are experimenting with nematode-resistant radishes, used as "trap crops," to reduce nematicide use in sugar beet-barley, sugar beet-bean, and sugar beet-corn rotations. When nematodes enter the tissue of a trap crop, they survive but cannot reproduce.

Additional benefits from this approach to pest control may include protection of soil from wind erosion, capture of soil nitrates, and stabilization of income by integrating livestock into cropping systems. For more information, contact David W. Koch, Project Coordinator, University of Wyoming, Research & Extension Agronomist, Department of Plant, Soil and Insect Science, P.O. Box 3354, University Station, Laramie, WY 82071-3354; (307)766-3242.

Research To Show Benefits Of Well-Managed Forests

Six timber harvesting demonstration/study replicates in Pennsylvania, funded by the SARE program, are helping researchers to examine the economic and environmental benefits of proper farm woodlot management, including improved air and water quality, wood products, recreational opportunities, and wildlife habitat. Each 12-acre replicate consists of six two-acre treatments: a control and five timber harvesting practices. Growth responses will be measured, and stand structure and species composition are expected to be altered.

The research will enhance the adoption of a forest stewardship ethic by farmers, timber harvesters, other landowners, and extension agents by demonstrating the impacts of various silvicultural options. Researchers will also determine the economics of sustainable forestry practices and potential contributions to the whole farm budget. For more information, contact Stephen B. Jones and James C. Finley, Co-Project Coordinators, School of Forestry, Pennsylvania State University, 110 Ferguson Building, University Park, PA 16802; (814)863-0401.

Use of Conservation Tillage on the Increase, Survey Finds

Conservation tillage, either no-till, ridge-till or mulch-till, has been used on approximately an additional 9 million acres a year for the last two years, according to the 1993 national crop residue management survey by the Conservation Technology Information Center. Conservation tillage leaves 30 percent or more of the residues from previous crops on the ground after planting. The survey found that conservation tillage accounted for more than 97 million acres, or nearly 35 percent of total cropland acres planted in 1993. Almost 39 percent, or nearly 108 million acres, is being clean tilled, leaving little or no residue.

The survey includes a 15-30 percent residue category which is not a form of conservation tillage, but may represent a positive system for soil erosion control. Combined with other conservation practices like strip cropping, terraces, and rotations, 15-30 percent residue levels can provide adequate erosion control. Adding the 15-30 percent category to conservation tillage acres, more than 170 million acres, or 61 percent of the 278 million planted acres in the United States, utilized some form of crop residue management.

Guide for authors

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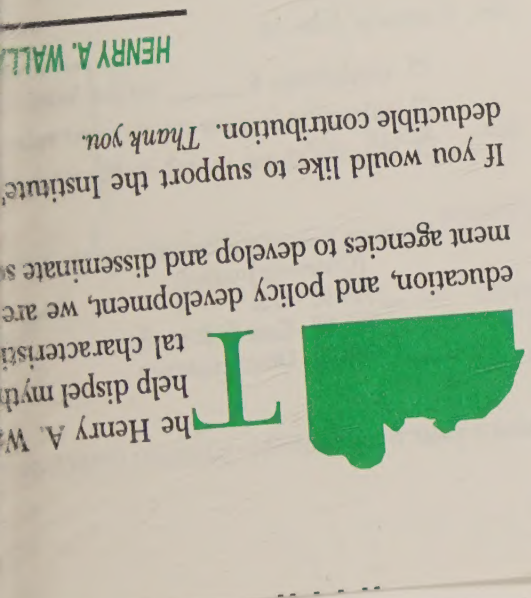
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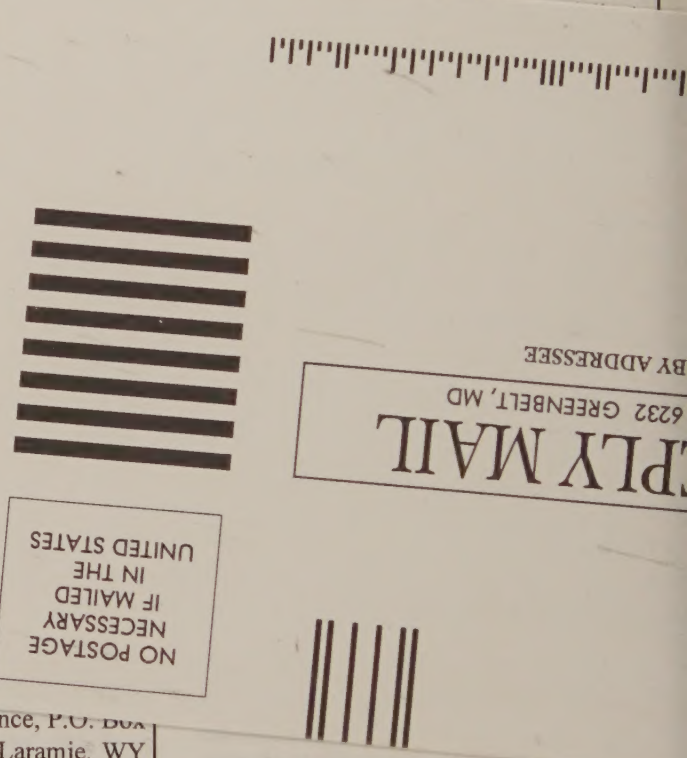

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Research papers should use the International (SI, or metric) system throughout. Occasional use of common unit equivalents in parentheses is permitted, mainly for relatively exotic SI units.

Title page

The title page should give the following information (all flush left): 1) title of the paper; 2) names of authors; 3) affiliation and office address of authors, and 4) acknowledgements, if any. See examples in this issue of AJAA.

Abstract

The abstract should be 200 to 400 words suitable for readers from a broad range of disciplines. It should avoid highly-specialized terminology that might be appropriate for a single discipline journal. Take particular care that the significance of the work is made clear, even to readers from a different field.

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How you can help support the scientific and educational needs of a sustainable agricultural system

A growing number of Americans have become concerned about the long-term sustainability of our food production system. Farmers and agricultural scientists are among those raising questions about the growing dependence of modern farming on nonrenewable resources, the depletion of our resource base through soil erosion, and heavy reliance on chemical fertilizers and pesticides. Continued heavy reliance on farm chemicals is questioned because they have become an expensive production input. Their widespread use also raises questions about human and animal health, food quality and safety, environmental quality, and the continued demise of the family farm.

Low-input alternative farming methods address these economic and environmental challenges. Alternative production systems point the way toward more profits, more individual choice, and long-term sustainability for our food system. More must be done to develop effective ways to make sure research, education, and information sources are readily available to farmers who want to adopt these techniques.

The Henry A. Wallace Institute for Alternative Agriculture needs your help in meeting this challenge. We are a nonprofit tax-exempt research and education organization formed to encourage and facilitate the adoption of low cost, resource conserving, and environmentally sound farming methods. We work directly with government agencies, colleges and universities, producer groups, and other institutions that provide research, education and information services to farmers.

The Institute also provides these services:

- *A resource to lawmakers and others who influence agricultural research, education, and information policy*
- *A voice for alternative agriculture in Washington*
- *A sponsor of research and education outreach programs*
- *A national clearinghouse for information on alternative agriculture*
- *A publisher of reliable scientific information on agricultural sustainability*

If you're interested in helping us, please contact the Henry A. Wallace Institute for Alternative Agriculture, 9200 Edmonston Road, Greenbelt, MD 20770. The phone number is (301) 441-8777.

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